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PRODUCT DATA REPRESENTATION AND EXCHANGE

Part: 230 **Title:** Building Structural Frame: Steelwork

Purpose of the document as it relates to target document is:

__X__ **Primary Content** **Current Status:** Working Draft

_____ **Issue Discussion**

_____ **Alternate Proposal**

_____ **Partial Content**

ABSTRACT:

This part of ISO 10303 documents the Application Protocol for the exchange of information relating to structural steel frames. The computer applications to which it relates are those providing analysis, member design, connection design, and detailing functions for the designers and constructors of buildings.

KEYWORDS:

Building, Structure,
Structural Element,
Structural Frame,
Steelwork,
Application Protocol

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Foreword

The International Organization for Standardization (ISO) is a world-wide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with the ISO, also take part in the work. ISO collaborates with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75% of the member bodies casting a vote.

International Standard ISO 10303 230 was prepared by Technical Committee ISO/TC 184 *Industrial automation systems and integration*, Subcommittee SC4 *Industrial data and global manufacturing programming languages*.

ISO 10303 currently consists of the following parts under the general title *Industrial automation systems and integration - Product data representation and exchange*:

– Part 1, Overview and fundamental principles;

– Part 11, Description methods: The EXPRESS language reference manual;

– Part 12, Description methods: The EXPRESS-I language reference manual;

– Part 21, Implementation methods: Clear text encoding of the exchange structure;

– Part 22, Implementation methods: Clear text encoding of the exchange structure;

– Part 31, Conformance testing methodology and framework: General concepts;

– Part 32, Conformance testing methodology and framework: Requirements on testing laboratories and clients;

– Part 33, Conformance testing methodology and framework: Abstract test cases;

– Part 41, Integrated generic resources: Fundamentals of product description and support;

– Part 42, Integrated generic resources: Geometric and topological representation;

– Part 43, Integrated generic resources: Representation structures;

– Part 44, Integrated generic resources: Product structure configuration;

– Part 45, Integrated generic resources: Materials;

– Part 46, Integrated generic resources: Visual presentation;

– Part 47, Integrated generic resources: Shape variation tolerances;

- Part 49, Integrated generic resources: Process structure and properties;
- Part 101, Integrated application resources: Draughting;
- Part 104, Integrated application resources: Finite element analysis;
- Part 105, Integrated application resources: Kinematics;
- Part 201, Application protocol: Explicit draughting;
- Part 201, Application protocol: Associative draughting;
- Part 203, Application protocol: Configuration controlled design;
- Part 204, Application protocol: Mechanical design using boundary representation;
- Part 205, Application protocol: Mechanical design using surface representation;
- Part 207, Application protocol: Sheet metal die planning and design;
- Part 210, Application protocol: Printed circuit assembly product design data;
- Part 213, Application protocol: Numerical control process plans for machined parts;
- Part 230, Application protocol: Building Structural Frame: Steelwork;
- Part 501, Application interpreted construct: Edge-based wireframe;
- Part 502, Application interpreted construct: Shell-based wireframe;
- Part 503, Application interpreted construct: Geometrically bounded 2D wireframe;
- Part 504, Application interpreted construct: Draughting annotation;
- Part 505, Application interpreted construct: Drawing structure and administration;
- Part 506, Application interpreted construct: Draughting elements;
- Part 507, Application interpreted construct: Geometrically bounded surface;
- Part 508, Application interpreted construct: Non-manifold surface;
- Part 509, Application interpreted construct: Manifold surface;
- Part 510, Application interpreted construct: Geometrically bounded wireframe;
- Part 511, Application interpreted construct: Topologically bounded surface;
- Part 512, Application interpreted construct: Faceted boundary representation;
- Part 513, Application interpreted construct: Elementary boundary representation;
- Part 514, Application interpreted construct: Advanced boundary representation;
- Part 515, Application interpreted construct: Constructive solid geometry;

- Part 516, Application interpreted construct: Mechanical design context;
- Part 517, Application interpreted construct: Mechanical design geometric presentation;
- Part 518, Application interpreted construct: Mechanical design shaded presentation.

The numbering of the parts of the International Standard reflects its structure:

- Parts 11 and 12 specify the description methods,
- Parts 21 to 25 specify the implementation methods,
- Parts 31 to 33 specify the conformance testing methodology and framework,
- Parts 41 to 49 specify the integrated generic resources,
- Parts 101 to 105 specify the integrated application resources,
- Parts 201 to 230 specify the application protocols, and
- Parts 501 to 518 specify the application interpreted constructs.

Should further parts be published, they will follow the same numbering pattern.

Annexes A, B, C, D, and E of this document form an integral part of this part of ISO 10303. Annexes F, G, and H are for information only.

Introduction

ISO 10303 is an international standard for the computer-interpretable representation and exchange of product data. The objective is to provide a neutral mechanism capable of describing product data throughout the life cycle of a product, independent from any particular system. The nature of this description makes it suitable not only for file exchange but also as a basis for implementing and sharing for product databases and archiving.

This International Standard is organized as a series of parts, each published separately. The parts of ISO 10303 fall into one of the following series: description methods, integrated resources, application integrated constructs, application protocols, abstract test suites, implementation methods, and conformance testing. The series are described in ISO 10303-1. This part of ISO 10303 is a member of the application protocol series.

This part of ISO 10303 specifies an application protocol (AP) for the representation and exchange of information relating to structural steel frames. The computer applications to which it relates are those providing analysis, member design, connection design, and detailing functions for the designers and constructors of buildings.

Although the use of information technology (IT) is increasing rapidly within construction, no product information based open standards yet exist for the industry. Applications used in different domains often employ very different systems, and, where data exchange does take place, it is on an ad-hoc basis. This part of ISO 10303 addresses the growing need for an integrated approach to the use of IT within building construction.

Product data relating to steel structures is represented in a model which captures analysis, design, and manufacturing views. Areas of the model relating to analysis describe the connectivity of elements and nodes; areas of the model relating to design describe the geometry and assembly of parts and connectors; and areas of the model relating to manufacturing describe the physical location and properties of parts and joints.

The model is based closely on the CIMsteel Integration Standards (CIS) - which were the main deliverable of the Eureka 130 CIMsteel project. The CIMsteel project was aimed at improving the efficiency and effectiveness of the European constructional steelwork industry through the introduction of computer integrated manufacture (CIM). The CIS are ISO-aligned and were designed to offer the industry an interim solution to data exchange while providing firm foundations for the development of an ISO standard. It was envisaged that this “twin track” approach would provide a clear migration route from CIS to ISO based technology.

This application protocol defines the context, scope and information requirements for the representation and exchange of information relating to structural steel frames and specifies the integrated resources necessary for satisfying those requirements.

Application Protocols provide the basis for developing implementations of ISO 10303 and abstract test suites for conformance testing of AP implementations.

Clause 1 defines the scope of the application protocol and summarizes the functionality and data covered by the AP. An application activity model that is the basis for the definition of the scope is provided in annex F. The information requirements of the application are specified in clause 4 using terminology appropriate to the application. A graphical representation of the information requirements, referred to as the application reference model, is given in annex G.

Resource constructs are interpreted to meet the information requirements. This interpretation produces the application interpreted model (AIM). This interpretation, given in 5.1, shows the

correspondence between the information requirements and the AIM. The short listing of the AIM specifies the interface to the integrated resources and is given in 5.2. Note that the definitions and EXPRESS provided in the integrated resources for constructs used in the AIM may include select list items and subtypes which are not imported into the AIM without annotation. A graphical representation of the AIM is given in annex H. Additional requirements for specific implementation methods are given in annex D.

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Industrial automation systems - Product data representation and exchange - Part 230: Application protocol: Building Structural Frame: Steelwork

1 Scope

This part of ISO 10303 specifies the use of integrated resources to satisfy requirements for the exchange of computer-interpretable information relating to structural steel building frames - which are considered purely from the standpoint of a structural engineer.

The life-cycle of a building can be decomposed into five separate stages: (i) plan, (ii) design, (iii) construct, (iv) use (including operate and maintain), and (v) demolish. AP230 supports the exchange of data during the first three stages of this list.

> NOTE 1 - The application activity model (AAM) presented in annex F provides a graphical representation of the processes and information flows which relate to the planning, design and construction stages of a building life cycle and indicates which processes and information flows form the basis of this scope statement.

The first three stages of a building life cycle - plan, design, and construct - are completed as the result of planning, design, construction and (ongoing) management activities.

The planning and management of building quality results in the generation of project technical specifications and applicable standards - both of which govern design. In turn, project planners and managers make use of feedback from design and construction activities. In the case of steel-framed buildings, design activities generate steelwork schedules, detailed designs, general arrangements and various types of feedback to project managers and planners. Input from designers informs and directs the fabricators and erectors of steel-framed building superstructures. Of these information flow and activities, AP230 addresses: the transfer of quality-specification information into design, design activities, the feedback of information from designers to project planners / managers, the transfer of information into fabrication and erection, and the feedback of information from fabricators and erectors to project planners / managers. Under design activities, AP230 addresses: structural design, loading assessment, structural scheme modelling, structural analysis, member design, connection design, and steelwork detailing.

The products addressed by AP230 - steelwork building frames and their components - are employed in low, medium and high rise construction in domestic, commercial and industrial applications. The AP is applicable to a variety of structures ranging from simple, single-storey portal frame industrial buildings to multi-storey office blocks. The main structural steelwork is covered, as is secondary steelwork - such as purlins, siderails, cleats and cladding. The frames considered may be braced or unbraced. Connections can be pinned, rigid, or semi-rigid - rigid and semi-rigid being full or partial strength. The data model underlying this AP views frames as being fabricated from manufacturing assemblies, and views manufacturing assemblies as being made up of parts and joint systems. Parts may be prismatic, prismatic-derived or two dimensional.

> EXAMPLES
>
> 1. - A prismatic part is, typically, a rolled section.
>
> 2. - Prismatic-derived parts include castelated and tapered beams.

3. - Two dimensional parts include plates and sheets.

The AP includes support for rolled, welded, cast, or cold-formed parts (although only limited information is held on cast and cold-formed parts).

Welded and bolted joint systems are covered, and bolted joint systems may involve ordinary and pre-loaded bolts.

In general terms, the data supported by AP230 include: geometrical and geographical data, data relating to physical and material characteristics, data relating to structural behaviour, data relating to unique identification, logical grouping data, and temporal data. These data types can also be described - more specifically - in terms of the sorts of entity to which they relate.

This part of ISO10303 specifies the following:

- persons and organizations (names and addresses)
- projects (descriptions)
- sites (descriptions and locations)
- analytical models (connectivity and properties of elements and nodes)

EXAMPLE 4. - Element properties considered by AP230 include elastic and plastic behaviours, temperature related material strengths, thickness related material strengths, and multi-linear elasticities.

- loads (values of basic cases and combinations)

EXAMPLE 5. - Loads considered by AP230 include dead loads, imposed loads, wind loads, snow loads, and equivalent static loads (for seismic / dynamic analysis). Element loads may be applied to global or local axes, and may be destabilising.

- analysis results (sets of values of forces at nodes and within elements)
- design assemblies (connectivity and descriptions of members, connections, and frames)
- structures (locations, connectivity, and characteristics of parts, joints and sub-assemblies)

EXAMPLES

6. - Part-modifications covered by AP230 include notches and chamfers, skews, hole groups.

7. - Part-descriptions supported by AP230 include references to standard and manufacturers' items, and representation in terms of implicit geometry.

The following are outside the scope of this part of ISO 10303:

- complex parts,
- complex features,
- complex joint systems,
- curved prismatic parts,
- non-isotropic materials,

– non-standard fabricated beams,

EXAMPLE 8. - A typical fabricated beam is a plate girder.

– crane rails,

– compound beams,

– second order elastic analysis,

– holding down bolts,

– studs (used in joint systems),

– threaded rods,

– pins,

– cambered beams,

NOTE 2 - Cambered beams will have been included in AP230 by the time this part of 10303 reaches Committee Draft stage.

– dimensional tolerances,

– bearing surfaces,

– elastic bearings,

– movement joints,

– dynamic / cyclic loading,

EXAMPLE 9. - Typical sources of dynamic loads are earthquakes, explosions, and vibration.

– moving loads

EXAMPLE 10. - A typical moving load is a highway load.

NOTE 3 - If represented as equivalent static loads, seismic loads can be accommodated by the current Application Reference Model for AP230. The ARM may be extended to included explicit provision for dynamic loading.

– 3D solid modelling and detailed FEA,

– cost issues,

– organizational issues (within and between companies),

– composite construction, and

NOTE 4 - shear studs will have been included in AP230 by the time this part of 10303 reaches Committee Draft stage.

– contractual arrangements.

NOTE 5 - AP230 may be applicable to related structures such as bridges, transmission towers, and offshore structures, but is not specifically aimed at such structures.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 10303. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 10303 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO Directives, *Part 3, Drafting and presentation of International Standards.*

ISO 10303-41:1993, I*ndustrial automation systems - Product data representation and exchange - Part 41: Integrated generic resources: Fundamentals of product description and support.*

ISO 10303-42:1993, *Industrial automation systems - Product data representation and exchange - Part 42: Integrated generic resources: Geometric and topological representation.*

ISO 10303-43:1993, *Industrial automation systems - Product data representation and exchange - Part 43: Integrated generic resources: Representation structures.*

ISO 10303-44:1993 *Industrial automation systems - Product data representation and exchange - Part 44: Integrated generic resources: Product structure configuration.*

3 Definitions and abbreviations

3.1 Terms defined in ISO 10303-1

This part of ISO 10303 makes use of the following terms defined in ISO 10303-1:

- application;
- application activity model (AAM);
- application interpreted model (AIM);
- application protocol (AP);
- application reference model (ARM);
- conformance testing;
- implementation method:
- integrated resource;
- product;
- product data;

– unit of functionality (UoF).

3.2 Terms defined in ISO 10303-31

This part of ISO 10303 makes use of the following terms defined in ISO 10303-31:

– Abstract test suite (ATS);

– Conformance class;

– Protocol information and conformance statement (PICS).

3.3 Other definitions

For the purposes of this part of ISO 10303, the following definitions apply:

3.3.1 building: see ISO 6707-1

3.3.2 structure: a product which results from a construction operation and which uses an organized combination of connected parts designed to provide some degree of rigidity.

3.3.3 site: see ISO 6707-1

3.4 Abbreviations

For the purposes of this part of ISO 10303, the following abbreviations apply:

AAM	Application Activity Model
AEC	Architecture, Engineering, and Construction
AIM	Application Interpreted Model
AP	Application Protocol
ARM	Application Reference Model
ATS	Abstract Test Suite
UoF	Unit of Functionality
PICS	Protocol Information and Conformance Statement

4 Information requirements

This clause specifies categories of information, relating to steel building frames, which structural-engineering applications supported by this AP will include.

The information requirements are specified as a set of units of functionality, application objects, and application assertions. These assertions pertain to individual application objects and to relationships between application objects and are defined in terminology of the AP domain.

NOTES

1 - A graphical representation of the information requirements is provided in annex G.

2 - The information requirements correspond to activities identified as being within the scope of the AP in annex F.

3 - The mapping table provided in clause 5.1 shows how the information requirements are met

4.1 Units of functionality

This subclause specifies the units of functionality for the Building Structural Frame: Steelwork AP. This part of ISO 10303 specifies the following units of functionality:

- project_brief UoF
- analysis_results UoF
- overall_structural_design UoF
- structural_scheme UoF
- design_loading UoF
- load_case_combinations UoF
- basic_load_cases UoF
- structural_models UoF
- member_design_information UoF
- connection_design_information UoF
- detailed_designs UoF

The units of functionality and a description of the functions that each UoF supports are given below. The application objects included in the UoFs are defined in clause 4.2.

4.1.1 project_brief UoF

The **project brief** is produced by the *manage overall design* activity and is required by the *produce concept design* activity. It comprises relevant areas of the client's brief, and it forms the basis of initial concept design. This information is used to create the scheme design and much of it is descriptive rather than numeric. There are currently no applications specifically aimed at the generation of project briefs.

NOTE - The *manage overall design* activity is node A21 of the application activity model (AAM) presented in annex F and the *produce concept design* activity is node A22.

The project_brief UoF, thus, holds information about the project, the site(s), and the structure(s); and information about the basis for the design: the structure’s use, its design life, number of storeys, maximum and minimum dimensions, loadings, and environment.

The following application objects are used by the project_brief UoF:

- project
- site
- structure
- address
- person_and_organization
- person
- organization

4.1.2 analysis_results UoF

Analysis results are produced by the *perform analysis* activity and is required by the *design members* and *design connections* activities. They comprise the results of analysis of the structural models, and describe the response of the structure to the design loading. Many current applications generate analysis results (although a more selective presentation of results would be desirable).

NOTE - The *perform analysis* activity is node A255 of the AMM presented in annex F, the *design members* activity is node A32, and the *design connections* activity is node A33.

The analysis_results UoF, thus, holds the results of the analysis after a wire frame model (or FEM) has been created, loaded and analysed.

The following application objects are used by the analysis_results UoF:

- analysis
- analysis_group
- analysis_model
- analysis_result
- analysis_result_set
- basic_load_case
- basic_results
- combined_results
- element
- element_displacement
- element_force
- element_group
- element_result
- elmnt_displmt_at_node

- elmnt_node_result
- elt_node_connectivity
- end_force
- envelope_results
- loading_combination
- node
- node_displacement
- node_group
- node_result
- support_reaction
- group

4.1.3 overall_structural_design UoF

The **overall structural design** is produced by the *develop structural design* activity and is required by the *manage detail design*, *design members*, and *design connections* activities. It comprises information existing after analysis but before member and connection design and it may relate to a number of structural models. The overall structural design represents a major embellishment of the initial scheme design. As part of the *develop structural design* activity, the information gathered from the analysis is assessed - usually in terms of overall serviceability (principally deflection of the structure) - to see whether the initial estimates of the main members are suitable. If they are not suitable, the sections may be changed and the analysis performed again. Much of the information contained in an overall structural design is still descriptive. By the time such a design has been produced, analysis will have demonstrated the stability of the structure, but the cross-over from analysis to design requires a certain amount of “engineering judgement”. Structures are always simplified for analysis, and often only a small portion of a complete structure is analysed. At the design stage, (the design members activity) a typical member will be designed on the basis of analysis results for a number of elements (taking the “worst case” conservative approach). Structural design activities are generally supported by existing analysis applications; and are still more extensively supported by newer applications which represent structures in terms of members rather than in terms of elements.

NOTE - The *develop structural design* activity is node A252 of the AMM presented in annex F, the *manage detail design* activity is node A31, the *design members* activity is node A32, the *design connections* activity is node A33, and the *develop structural design* activity is node A252.

The overall_structural_design UoF, thus, holds a description of the analysed design, indicating the position, type and initial size of the structural elements required to ensure the design fits the requirements. It contains the structural concept, layout, and specification for the main structural members - information required by the structural engineering designer for member and connection design.

The following application objects are used by the overall_structural_design UoF:

- analysis_model

- angle_sect
- asbly_connection
- assembly
- assembly_group
- circle_sect
- connector
- coord_system
- design_assembly
- design_criteria
- design_part
- drawing
- effective_buckling_length
- elasticity
- element
- element_eccentricity
- element_group
- elt_node_connectivity
- frame_group
- functional_role
- geometric_representation
- gridline
- gridline_set
- I_type_sect
- material
- material_properties
- material_strength
- node
- node_group

- point
- prismatic_part
- prismatic_part_geometry
- project
- pseudo_prismatic_part
- rectangle_sect
- release
- schedule
- section_profile
- section_properties
- sheet_part
- sheet_part_geom
- site
- structure
- struc_connection
- struc_frame
- struc_member
- str_conn_group
- str_member_group
- s_part
- tapered_pp
- transformation
- T_type_sect

4.1.4 structural_scheme UoF

The **structural scheme** is produced by the *develop structural design* activity and is required by the *assess loading* and *model structural scheme* activities. It is essentially a sketch design - which includes preliminary sizes and positions of some of the main members - and may be thought of as the “stick diagram”. The structural scheme provides the basis for the idealization of the structure, beginning with the structure as a whole. It identifies key members, and the method of providing lateral stability, but it provides little detail as to how the “sticks” really fit together. Much of the information provided by a scheme is descriptive rather than numeric and the production structural

schemes is not really addressed by current applications. Suitable applications may, however, appear within the next few years.

NOTE - The *develop structural design* activity is node A252 of the AMM presented in annex F, the *assess loading* activity is node A253, and the *model structural scheme* activity is node A254.

The structural_scheme UoF, thus, holds structural layouts, associated member sizes, calculations and textual descriptions of the structure.

The following application objects are used by the structural_scheme UoF:

- analysis
- angle_sect
- asbly_connection
- assembly
- assembly_group
- bolt
- bolt_mechanism
- bolt_system
- boundary_condition
- circle_sect
- coord_system
- design_assembly
- design_criteria
- design_part
- drawing
- effective_buckling_length
- elasticity
- frame_group
- functional_role
- geometric_representation
- gridline
- gridline_set
- I_type_sect

- layout
- material
- material_properties
- material_strength
- nut
- point
- prismatic_part
- prismatic_part_geometry
- rectangle_sect
- restraint
- schedule
- section_profile
- section_properties
- sheet_part
- sheet_part_geom
- struc_connection
- struc_frame
- struc_member
- str_conn_group
- str_member_group
- s_joint_system
- s_part
- tapered_pp
- trace
- trace_segment
- transformation
- T_type_sect
- washer

- weld_mechanism
- weld_system

4.1.5 design_loading UoF

The **design loading** is produced by the *assess loading* activity and is required by the *model structural scheme* activity. It comprises general floor/wall/roof loading - a loading schedule including characteristic loads (g_k, q_k, w_k) and partial factors of safety (γ_f). Most applications do not cover the assessment of loading as a separate item; and loading often has to be applied to elements or nodes, rather than to floors etc.

NOTE - The *assess loading* activity is node A253 of the AMM presented in annex F, and the *model structural scheme* activity is node A254.

The design_loading UoF, thus, holds the predicted loads on the structure which are used to create load cases.

The following application objects are used by the design_loading UoF:

- basic_load_case
- dead_load
- environmental_load
- imposed_load
- site
- snow_load
- structure
- wind_load

4.1.6 load_case_combinations UoF

The **load case combinations** are produced by the *model structural scheme* activity and are required by the *perform analysis* activity. They include serviceability or ultimate loading and most analysis applications cover them as part of a larger program.

NOTE - The *model structural scheme* activity is node A254 of the AMM presented in annex F, and the *perform analysis* activity is node A255.

The load_case_combinations UoF, thus, holds multiple combinations of the basic load cases which are to be used during analysis.

The following application objects are used by the load_case_combinations UoF:

- analysis
- basic_load_case
- loading_combination

– load_combination_occurrence

4.1.7 basic_load_cases UoF

The **basic load cases** are produced by the *model structural scheme* activity and are required by the *perform analysis* activity. They include dead, live, and wind load cases, and most analysis applications cover this as part of a larger program. Most currently available analysis applications cover basic load cases as part of a larger program - although it would be quite feasible to create a stand-alone module for the generation of such cases. Future applications may include facilities for the automatic generation of characteristic environmental loading from a map-like interface.

NOTE - The *model structural scheme* activity is node A254 of the AMM presented in annex F, and the *perform analysis* activity is node A255.

In summary, the basic_load_cases UoF holds analytical load cases, based upon the design loading, which are to be used during analysis.

The following application objects are used by the basic_load_cases UoF:

– basic_load_case

– conc_1d_elmnt_load

– conc_node_load

– dead_load

– distributed_1d_elmnt_load

– element

– element_load

– environmental_load

– imposed_load

– node

– snow_load

– wind_load

4.1.8 structural_models UoF

Structural models are produced by the *model structural scheme* activity and are required by the *perform analysis* activity. They are wire frame models (or FEMs)and are idealized analytical representations of the structure. Structural models are made up of nodes and elements, with associated material and geometric properties and boundary conditions. A single structure may require many structural models, and each model may be subjected to a number of load case combinations. Few current applications cover the integration of several analytical models into one structure, but software may soon develop in this area.

NOTE - The *model structural scheme* activity is node A254 of the AMM presented in annex F, and the *perform analysis* activity is node A255.

In summary, the structural_models UoF holds models of aspects of the structure to be used for analysis.

The following application objects are used by the structural_models UoF:

- analysis
- analysis_group
- analysis_model
- angle_sect
- boundary_condition
- circle_sect
- coord_system
- elasticity
- element
- element_eccentricity
- element_group
- elt_node_connectivity
- geometric_representation
- I_type_sect
- material
- material_properties
- material_strength
- node
- node_group
- point
- prismatic_part_geometry
- rectangle_sect
- release
- section_profile
- section_properties
- sheet_part_geom

- transformation
- T_type_sect

4.1.9 member_design_information UoF

Member design information is produced by the *design members* activity and are required by the *design connections*, and the *detail steelwork* activities. This is the information required to detail the members (section size, material spec, stiffeners, requirements for restraints, assumptions made during design etc.); it is precise and numeric in nature. By this stage of design, the main members have been shown to be of sufficient capacity to carry the expected loads. As they have yet to be detailed, there are no features associated with the members. Where members require restraints to prevent buckling, the positions and loading of these is part of the member design information. There are many applications which support member design.

NOTE - The *design members* activity is node A32 of the AMM presented in annex F, the *design connections* activity is node A33, and the *detail steelwork* activity is node A34.

In summary, the member_design_information UoF holds details of each member - which are required for detail design.

The following application objects are used by the member_design_information UoF:

- angle_sect
- asbly_connection
- assembly
- assembly_group
- circle_sect
- coord_system
- design_assembly
- design_criteria
- design_part
- effective_buckling_length
- elasticity
- frame_group
- functional_role
- geometric_representation
- gridline
- gridline_set
- I_type_sect

- material
- material_properties
- material_strength
- point
- prismatic_part
- prismatic_part_geometry
- pseudo_prismatic_part
- rectangle_sect
- restraint
- section_profile
- section_properties
- sheet_part
- sheet_part_geom
- struc_frame
- struc_member
- str_member_group
- s_part
- tapered_pp
- transformation
- T_type_sect

4.1.10 connection_design_information UoF

Connection design information is produced by the *design connections* activity and are required by the *detail steelwork* activities. This is the information required to detail the connections (plate sizes, bolts, nuts washers, material spec, stiffeners, requirements for restraints, assumptions made during design etc.). The information is precise and numeric in nature. By this stage of design, the connections (bolt groups, welds, etc.) have been shown to be of sufficient capacity to carry the expected loads. As they have yet to be detailed, there are no features associated with the connections. Where connections require restraint to prevent premature yielding, the positions and loading of these is part of the connections design information.

NOTE - The *design connections* activity is node A33 of the AMM presented in annex F, and the *detail steelwork* activity is node A34.

In summary, the connection_design_information UoF holds details of each connection - which are required for detail design.

The following application objects are used by the connection_design_information UoF:

- angle_sect
- asbly_connection
- assembly
- assembly_group
- bolt
- bolt_mechanism
- bolt_system
- circle_sect
- connector
- coord_system
- design_assembly
- design_criteria
- design_part
- elasticity
- functional_role
- geometric_representation
- gridline
- gridline_set
- I_type_sect
- layout
- material
- material_properties
- material_strength
- nut
- point
- prismatic_part
- prismatic_part_geometry

- pseudo_prismatic_part
- rectangle_sect
- section_profile
- section_properties
- sheet_part
- sheet_part_geom
- struc_connection
- struc_member
- str_conn_group
- s_joint_system
- s_part
- tapered_pp
- trace
- trace_segment
- transformation
- T_type_sect
- washer
- weld_mechanism
- weld_system

4.1.11 detailed_designs UoF

Detailed designs are produced by the *detail steelwork* (A34) activity and are required by the *construct & hand over building* activity. They are required for the fabrication and erection of the steelwork. The structural detailer takes member design information and connection design information and applies them to the "stick diagram" created in the structural scheme. During the process of design - which unfolds from the scheme design stage, members and connections may be modified. The detailer makes sure that the steelwork will actually fit together. The main difference between this detailed design stage and earlier stages is the requirement for features (notches, chamfers, holes, etc.).

NOTE - The *detail steelwork* activity is node A34 of the AMM presented in annex F, and the *construct & hand over building* activity is node A4.

Detailed design information is passed on to fabricators in order that they may begin the manufacturing process. At this point, each and every piece of steel in a structure should now be fully defined and detailed - with dimensions for every cutting and drilling operation required. Every bolt group, weld, end plate, stiffener, etc. should also be identified. Use of engineering judgement allows

the detailer to replicate details from one area to another. The details of the members, and the members themselves, may be rationalized in order to improve the efficiency of production. Many existing applications support detail design work.

In summary, detailed_designs UoF holds the detailed information, in various forms, necessary to construct the structure.

The following application objects are used by the detailed_designs UoF:

- angle_sect
- asbly_connection
- assembly
- assembly_group
- bolt
- bolt_mechanism
- bolt_system
- chamfer
- circle_sect
- coord_system
- cutting_plane
- drawing
- edge_chamfer
- elasticity
- geometric_representation
- gridline
- gridline_set
- hole
- I_type_sect
- joint_dep_feature
- layout
- located_feature
- located_joint_system
- located_part

- l_joint_systems_group
- l_parts_group
- manufact_asbly
- material
- material_properties
- material_strength
- notch
- nut
- part_joint
- prismatic_end_feature
- prismatic_part
- prismatic_part_geometry
- procedural_feat
- pseudo_prismatic_part
- rectangle_sect
- schedule
- section_profile
- section_properties
- sheet_part
- sheet_part_geom
- skewed_end
- structure
- s_feature
- s_joint_system
- s_part
- tapered_pp
- trace
- trace_segment

- transformation
- T_type_sect
- washer
- weld_mechanism
- weld_system

4.2 Application objects

4.3 Application assertions

5 Application interpreted model

6 Conformance requirements

Conformance to this part of ISO 10303 includes satisfying the requirements stated in this part, the requirements of the implementation method(s) supported, and the relevant requirements of the normative references.

An implementation shall support at least one of the following implementation methods:

– ISO 101303-21

Requirements with respect to implementation are specified in annex C.

The Protocol Information Conformance Statement (PICS) proforma lists the conformance classes and any conformance options that may be included in the conformance statement and subsequent testing. The PICS proforma is provided in annex D.

NOTE - ISO 10303-325 defines the abstract test suites to be used in the assessment of conformance. ISO 10303-32 describes the conformance assessment process.

This part of ISO 10303 provides for a number of options that may be supported by an implementation. These options have been grouped into the following conformance classes: Class 1 analysis, Class 2 member design, Class 3 connection design, and Class 4 detailing. Support for a particular conformance class requires support of all the options specified in this class.

Table 1 shows which of the ARM entities each of the classes include and exclude:

ARM entity	class 1	class 2	class 3	class 4
address				
analysis	**X**			
analysis_group				
analysis_model	**X**			
analysis_result	**X**			
analysis_results_set				
angle_sect				
asbly_connection				
assembly		**X**	**X**	**X**
assembly_group				
basic_load_case	**X**			
basic_results				
bolt			**X**	
bolt_mechanism			**X**	
bolt_system			**X**	
boundary_condition	**X**			
calendar_date	**X**	**X**	**X**	**X**
chamfer				

ARM entity	class 1	class 2	class 3	class 4
circle_sect				
combined_results				
conc_1d_elmnt_load	X			
conc_node_load	X			
connector			X	
coord_system				
cutting_plane				
date_and_time	X	X	X	X
dead_load				
design_assembly		X	X	
design_criteria				
design_part		X	X	
distributed_1d_elmnt_load	X			
drawing				
edge_chamfer				
effective_buckling_length				
elasticity	X	X	X	
element	X			
element_displacement				
element_eccentricity				
element_force				
element_group				
element_load	X			
element_result				
elmnt_displmnt_at_node	X			
elmnt_node_result	X			
elt_node_connectivity	X			
end_force	X			
envelope_results				
environmental_load				
frame_group				
functional_role				
geometric_representation	X	X	X	
gridline				
gridline_set				
group				
hole				
I_type_sect				
imposed_load				
instance_group	X	X	X	X
joint_dep_feature				
l_joint_systems_group				
l_parts_group				
layout			X	
load_combination_occurrence	X			
loading_combination	X			
local_time	X	X	X	X
located_feature				X

ARM entity	class 1	class 2	class 3	class 4
located_joint_system				X
located_part				X
manufact_asbly				X
material	X	X	X	
material_properties		X	X	
material_strength		X	X	
node	X			
node_displacement	X			
node_group				
node_result	X			
notch				
nut				
organization	X	X	X	X
part_joint				X
person	X	X	X	X
person_and_organization	X	X	X	X
point	X		X	
prismatic_end_feature				
prismatic_part		X	X	X
prismatic_part_geometry	X	X	X	
procedural_feat				
project	X	X	X	X
pseudo_prismatic_part				
rectangular_sect				
release	X			
restraint				
s_feature				X
s_joint_system			X	
s_part		X	X	X
schedule				
section_profile	X	X	X	
section_properties	X	X	X	
sheet_part				
sheet_part_geom				
site				
skewed_end				
snow_load				
steel_structural_frame_entity	X	X	X	X
steel_structural_frame_file	X	X	X	X
str_conn_group				
str_member_group				
struc_connection			X	
struc_frame				
struc_member		X	X	
structure	X	X	X	X
support_reaction	X			
T_type_sect				
tapered_part				

ARM entity	class 1	class 2	class 3	class 4
trace				
trace_segment				
trace_segment				
transformation				
washer				
weld_mechanism				
weld_system				
wind_load				

If an attribute references an entity that is outside the conformance class of its owner, that attribute is excluded from the conformance class of its owner. Any other attribute is included in the conformance class of its owner.

6.1 Conformance class 1: analysis

Conformance class 1 includes information required by, and produced by, activities that are associated with structural analysis.

This class is concerned with analytical models (comprising nodes, elements, boundary conditions, element geometry, material and end releases), loadings, load combinations, and analysis results.

6.2 Conformance class 2: member design

Conformance class 2 includes information produced by the activities that are associated with the design of structural members. Thus, it is concerned with design assemblies which may be structural frames or structural members. These design assemblies ultimately decompose into design parts and connectors. The design parts are specified by specific parts, which are more precisely defined in terms of material properties and geometry than were the equivalent analytical elements. The goal of activities covered by this conformance class is to determine whether structural members and frames are fit for purpose - in terms of serviceablity and ultimate strength.

This class is concerned with the concept that structural members are connected, and ultimately, that one part is connected to another. It is *not* concerned with how those connections are made.

6.3 Conformance class 3: connection design

Conformance class 3 includes information produced by the activities that are associated with the design of structural connections. Thus, it is concerned with design assemblies of the type structural connection, and their relationships with the associated structural members. These design assemblies ultimately decompose into design parts and connectors. The design parts are specified by specific parts - defined in terms of material properties and geometry. The connectors are specified by specific joint systems, which are either bolt systems or weld systems. It is concerned with whether Structural Connections are fit for their purpose, in terms of serviceablity and ultimate strength.

This class is concerned with how connections between structural members are made, and how each part is connected to another to form those connections. It is concerned with the specification of bolted and welded connections; i.e. how welds, bolts, nuts, washers and parts are geometrically arranged

6.4 Conformance class 4: detailing

Conformance class 4 includes information produced by the activities that are associated with the detailing of structural steelwork. Thus, it is concerned with manufacturing assemblies, and their relationship with the associated parts and joints. The located parts are specified by specific parts, defined in terms of material properties and geometry. the located joint systems are specified by specific joint systems, which are either bolt systems or weld systems. The located parts may be modified by a number of located features - specified by specific features.

This class is concerned with the dimensions of the physical components of a steelwork structure and with how those concepts are physically realized; i.e. how each part is connected to another, and how welds, bolts, nuts, washers and parts are geometrically arranged to form the complete structure.

Annex A
(normative)

AIM EXPRESS expanded listing

Annex B
(normative)

AIM short names of entities

Annex C
(normative)

Implementation method specific requirements

Annex D
(normative)

Protocol Information Conformance Statement (PICS) proforma

Annex E
(normative)

Information object registration

Annex F
(informative)

Application activity model

The application activity model (AAM) is provided to aid in understanding the scope and information requirements defined in this application protocol. The model is presented as a set of definitions of the activities and the data and a set of activity figures. The AAM covers activities which go beyond the scope of this application protocol.

The viewpoint of the Application Activity Model is that of a building-project manager.

F.1 Application activity model definitions

The following terms are used in the application activity model. Terms marked with an asterisk are outside the scope of this application protocol.

The definitions given in this text do not supersede the definitions given in the body of the text.

F1.1 Analysis Feedback: Information returned after analysis has taken place, to allow review cycles of the structural scheme, design loading, load cases, load case combinations and structural models.

F1.2 Analysis Results: Results of the analysis of the overall structural design.

F1.3 Analysis: Perform analysis on structural models using various load case combinations. Compile and review results with respect to extended brief and feed back results.

F1.4 Applicable Standards: Standards and specifications which will be followed during the design, fabrication and erection of the structure.

F1.5 Architectural design: The completed architectural design.

F1.6 Architectural Information: Information which reflects the extended brief e.g. set of scheme drawings.

F1.7 Assess Loading: Assess architectural scheme drawings and develop design loading.

F1.8 Basic Load Cases: Analytical load cases to be used during analysis: based upon the design loading.

F1.9 Building Regulations: Building regulations and applicable statutory requirements.

F1.10 Building Services Design Information: Information which reflects the building design requirements of the overall structure.

F1.11 Building Services Design: The completed building services design, supplied by the building services engineer.

F1.12 Building Services: Installed utility and facility systems.

F1.13 Client Brief: The client’s definition of his or her needs, indicating fundamental features required of the building, its functionality and its proposed location; and background information, i.e. public utilities information.

F1.14 Commission and Hand Over Building: Ensure any problems are rectified, clear the site and hand over building to its owners.

F1.15 Concept Design Information: Concept Information based upon the project brief: e.g. concept sketch designs.

F1.16 Concept Design: Develops initial sketch design based upon the project brief.

F1.17 Connection Design Information: Type (weld, bolt system etc) and related information (weld trace, bolt hole layout).

F1.18 Construct and Hand Over project: Construct structure in accordance to the developed design.

F1.19 Construct Substructure: Construct the substructure (piles / spread foundations) with respect to general arrangement and within the bounds set by the Overall Construction Plan.

F1.20 Construct Superstructure: Prepare the substructure and construct superstructure with respect to the General Arrangements and within the bounds set by the Overall Construction Plan.

F1.21 Construction Feedback: Feedback route to construction management from all aspects of the construction process.

F1.22 Contract Planning Information: Feedback route for contract information.

F1.23 Contract: Legal document of work.

F1.24 Cost Plan: Cost reports and plans to monitor/control costs throughout the project.

F1.25 Design Connection: Identify the connection type required and design, based upon the overall structural design, analysis results and the design of the actual members.

F1.26 Design Loading: The predicted loads on the structure used to create load cases.

F1.27 Design Members: Identify the steel information for each member, and produce general arrangements.

F1.28 Detail Design & Production Preparation: Add required detailed information to allow the construction of the structure.

F1.29 Detail Design Feedback: Feedback route for information to Overall Design, after a check for suitability of the member has been undertaken.

F1.30 Detail Design Management Feedback: Feedback route for information relevant to manage the detail design.

F1.31 Detail Development Plan: Combination of the overall structural design and detail design feedback, used to ensure that the detail design stays within the bounds set by the project management plans.

F1.32 Detail Steelwork: On completion of the member design, detailed designs and steelwork schedules are produced. Problems are returned via the detail design management.

F1.33 Detailed Designs: The detailed information in, various form, necessary to construct the structure.

F1.34 Develop Structural Design: From the architectural scheme drawings and initial design loads, develop a structural concept for analysis. After a series of analysis / design cycles, produce a structural scheme.

F1.35 Environment: Physical environment in which structure is to be built.

F1.36 Establish Site: Set up facilities and utilities and set out site.

F1.37 Extended Brief: The result of developing the client's brief into a comprehensive statement of requirements.

F1.38 Framed Structure: The finished structure.

F1.39 General Arrangement: Drawing of plans, elevations and sections, showing the sizes of all the members, setting out dimensions, and the layout of all the steelwork.

F1.40 Grid Lines and Datum: Establish building lines within the indicated site boundary, and a datum established to some known level or benchmark.

F1.41 Industry Standard Contracts: Legal agreements, laws, codes of practice, rules, corporate working requirements to be followed.

F1.42 Industry Standard Technical Specs: The totality of standards and specifications to which structures can be designed and constructed.

F1.43 Install Building Services: Install both utility and facility systems.

F1.44 Load Case Combinations: Multiple combinations of the basic load cases to be used during the analysis.

F1.45 Manage Construction Overall: Initiate and monitor the construction process and ensure that the construction stays within the bounds set by the Project Management Plans.

F1.46 Manage Detail Design: Initiate and monitor the detailed design, based upon the overall structural design and the feedback from the detailing and member design. The design is to stay within the bounds set by the project management plans.

F1.47 Manage Overall Design: Initiates and monitors overall design of the structure and ensures that the design stays within the bounds set by the project management plans. Relevant details are returned to project management.

F1.48 Manage Structural Design: Initiate and monitor overall architectural design of the structure and ensure that the design stays within the bounds set by the overall design development plan. Relevant details are returned to overall design management.

F1.49 Manage Total Project: Initiate, plan, monitor and control overall project.

F1.50 Management Feedback: missing definition.

F1.51 Member Design Information: Details of each member to enable detail design.

F1.52 Model Structural Scheme: From the structural scheme and design loading, develop structural models, basic load cases and combination load cases for analysis.

F1.53 Overall Architectural Design: Develops client's initial brief into a more complete extended brief with architectural scheme drawings. Relevant details are returned to design management.

F1.54 Overall Building Services Design: Develops the building services requirements, based upon the client's brief, the Architectural Information and the Environment. The Building Services Information is used in the Overall Structural Design.

F1.55 Overall Construction Plan: Plan to ensure that the construction stays within the bounds set by the Project Management Plans.

F1.56 Overall Design Development Plan: Combination of cost and design project plans, and time schedules to ensure overall design stays within the bounds set by the project management plans.

F1.57 Overall Design Feedback: Feedback route for relevant information to overall design management.

F1.58 Overall Design: Develop client's brief into a viable structural scheme.

F1.59 Overall Structural Design Feedback: Feedback route for relevant information to structural design management.

F1.60 Overall Structural Design: A description of the analysed design, indicating the position, type and initial size of structural elements required to ensure the design fits the requirements expressed by the Client Brief.

F1.61 Plan and Control Activities: Production of the initial time schedules and project plan, with continual monitoring via project management feedback to allow updates.

F1.62 Plan and Control Contracts: Contract organisation, monitoring and control activity.

F1.63 Plan and Control Costs: Production of the initial cost plan as required by the contractual requirements, with continual monitoring of the cost of the project and updating of the cost plan.

F1.64 Plan and Control Quality: Sets out what industry standards and specifications are to be used in the project, with continual monitoring of the effects and applicability of the standards and specifications via project management feedback loop.

F1.65 Plan and Control Tenders: Tender organisation, monitoring and control activity.

F1.66 Plan, Design and Construct a Structural Steelwork Building Project: The totality of processes required to design and construct a structure which meets the client's brief via a design / analyse review cycle. Construct structure using steel.

F1.67 Project Brief: Relevant areas of the client's brief, to allow an initial concept design.

F1.68 Project Contract Documents: The complete set of contractual documents for a project.

F1.69 Project Management Feedback: Management data fed back from all other activities, to allow the complete monitoring and control of the project.

F1.70 Project Management Plans: Combination of cost plan, project plan and time schedules which control all stages the project.

F1.71 Project Plan: Plan establishing activities in the project that are to be carried out, how they will be done and the order in which they will proceed.

F1.72 Project Record Documentation: Written documentation for the operation and maintenance of the completed structure, e.g. operation and maintenance manuals.

F1.73 Project Technical Specifications: The complete set of specifications used for a particular project.

F1.74 Resource Availability / Cost: The availability and cost of plant, labour and materials.

F1.75 Resources: Plant, labour and materials (both permanent and temporary), and associated data, e.g. costs, availability etc.

F1.76 Site Plan: Layout of the Site that the structure is to be built on.

F1.77 Steelwork Schedule: Schedule for the steelwork.

F1.78 Structural Design Development Plan: Combination of cost and design project plans, and time schedules to ensure that the structural design stays within the bounds set by the overall design development plans.

F1.79 Structural Models: Models of aspects of the structure to be used for analysis.

F1.80 Structural Scheme: Scheme indicating structural layouts, associated member sizes, calculations and textual descriptions of structure.

F1.81 Substructure: Completed spread foundations and piles of structure.

F1.82 Superstructure: Structural steel frame of the structure that sits supported by the substructure.

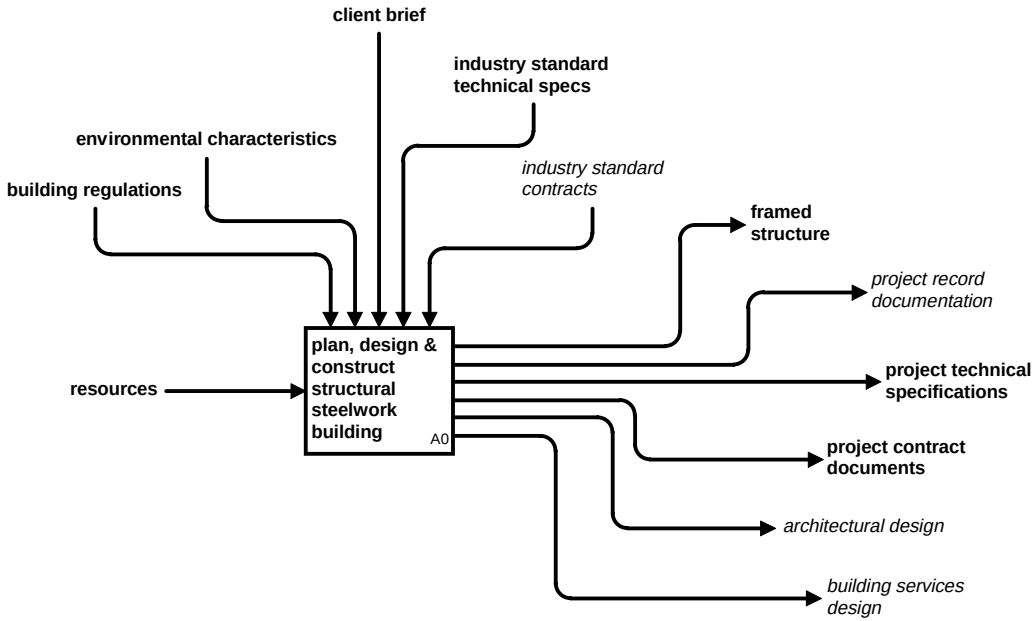
F1.83 Tender Planning Feedback: Feedback route for tender information.

F1.84 Time Schedules: Start and finish times of the activities set out in the Project Plan.

F.2 Application Activity Model diagrams

The AAM is presented in Figures F.2 to F.5. Activities and data flows which are out of scope are italicised.

USED AT:	AUTHOR: Mike Ward	DATE: 28/06/96		WORKING	READER DATE	CONTEXT:
	PROJECT: AP230	REV: 5.0	x	DRAFT		Top
				RECOMMENDED		
	NOTES: 1 2 3 4 5 6 7 8 9 10			PUBLICATION		



NODE: A-0	TITLE:	PAGE: 1

Figure F.1 - A-0: Plan, design, & construct structural steelwork building (context diagram)

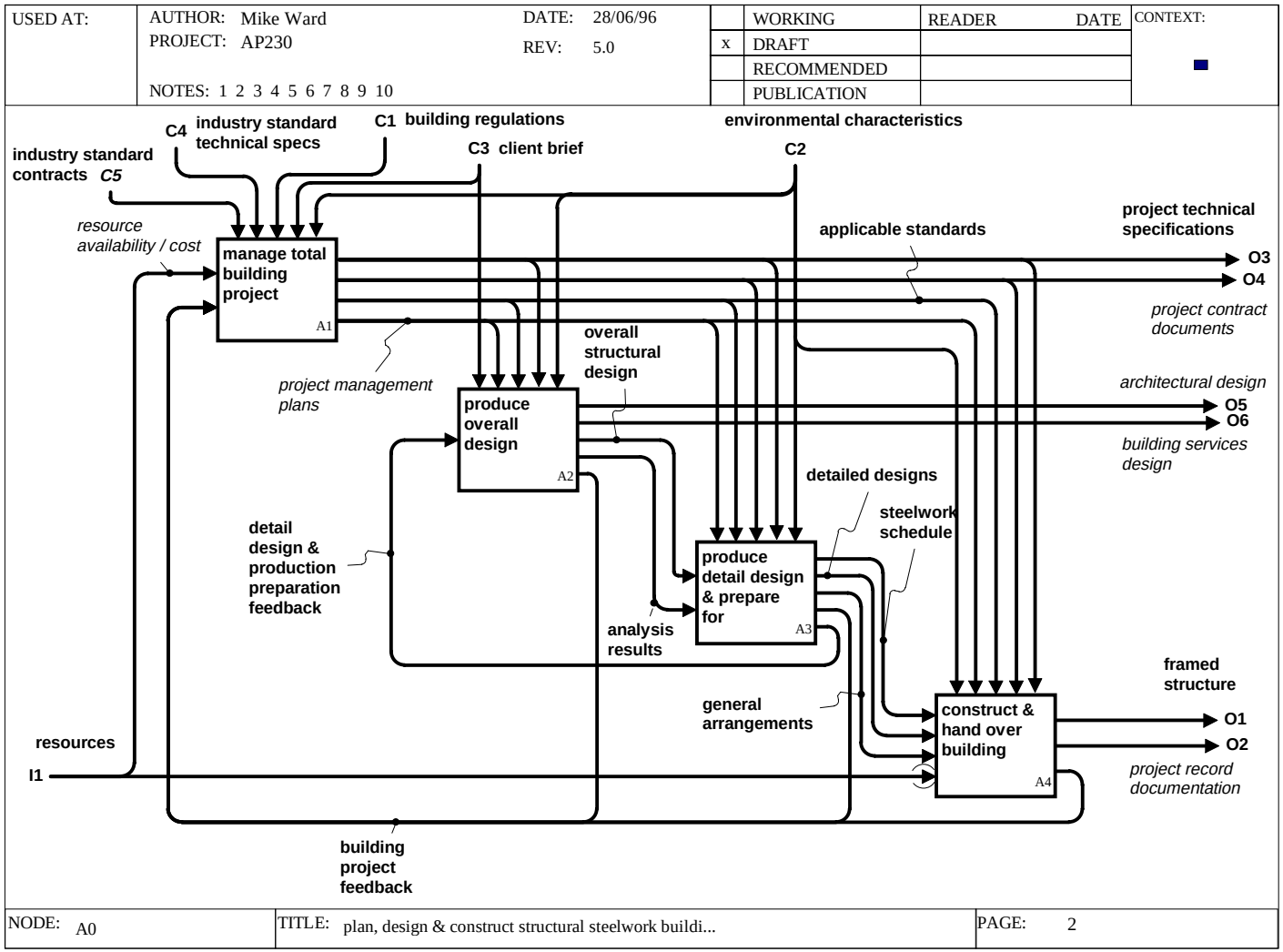


Figure F.2 - A0: Plan, design, & construct structural steelwork building

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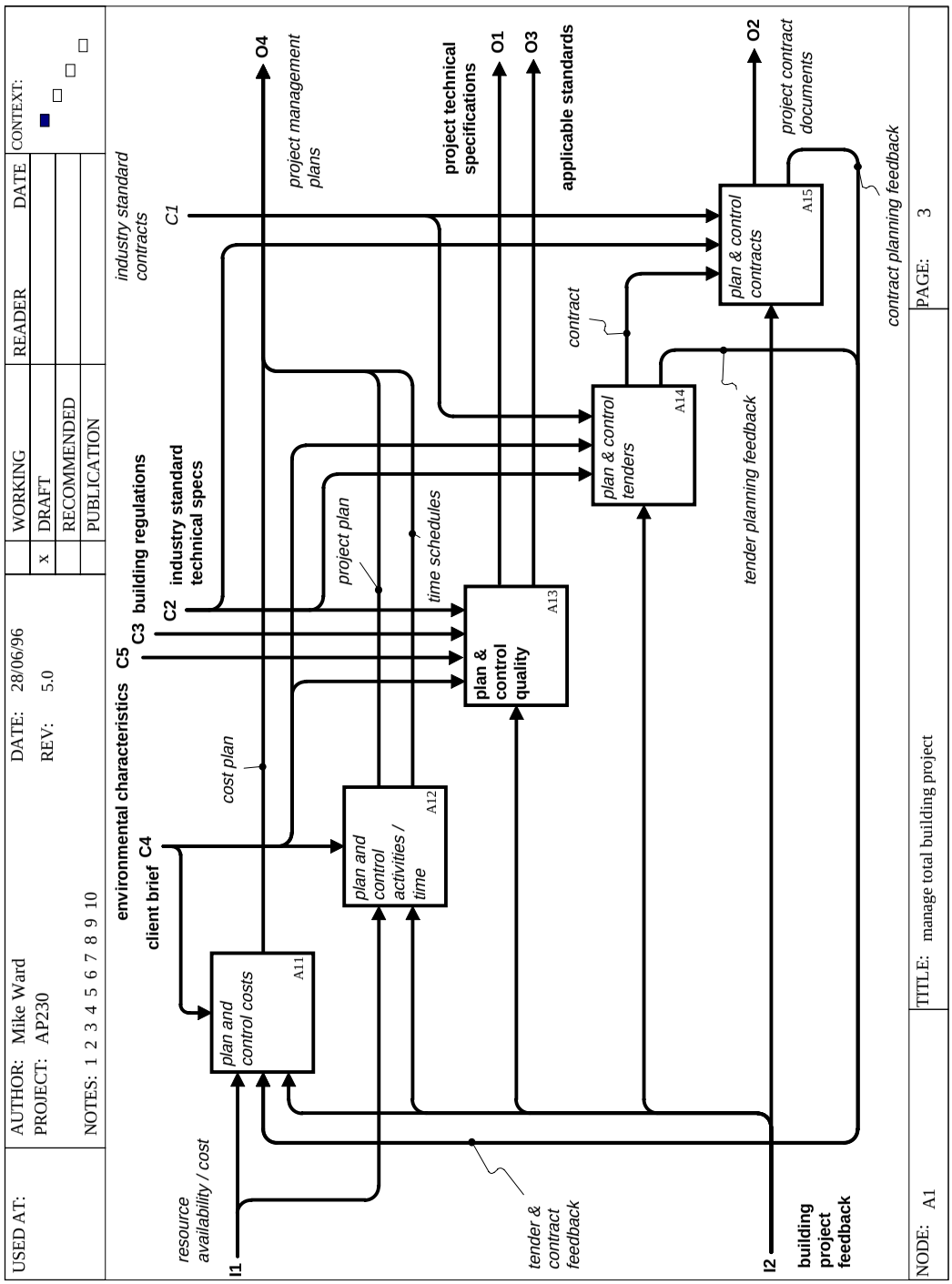

Figure F.3 - A1: Manage total building project

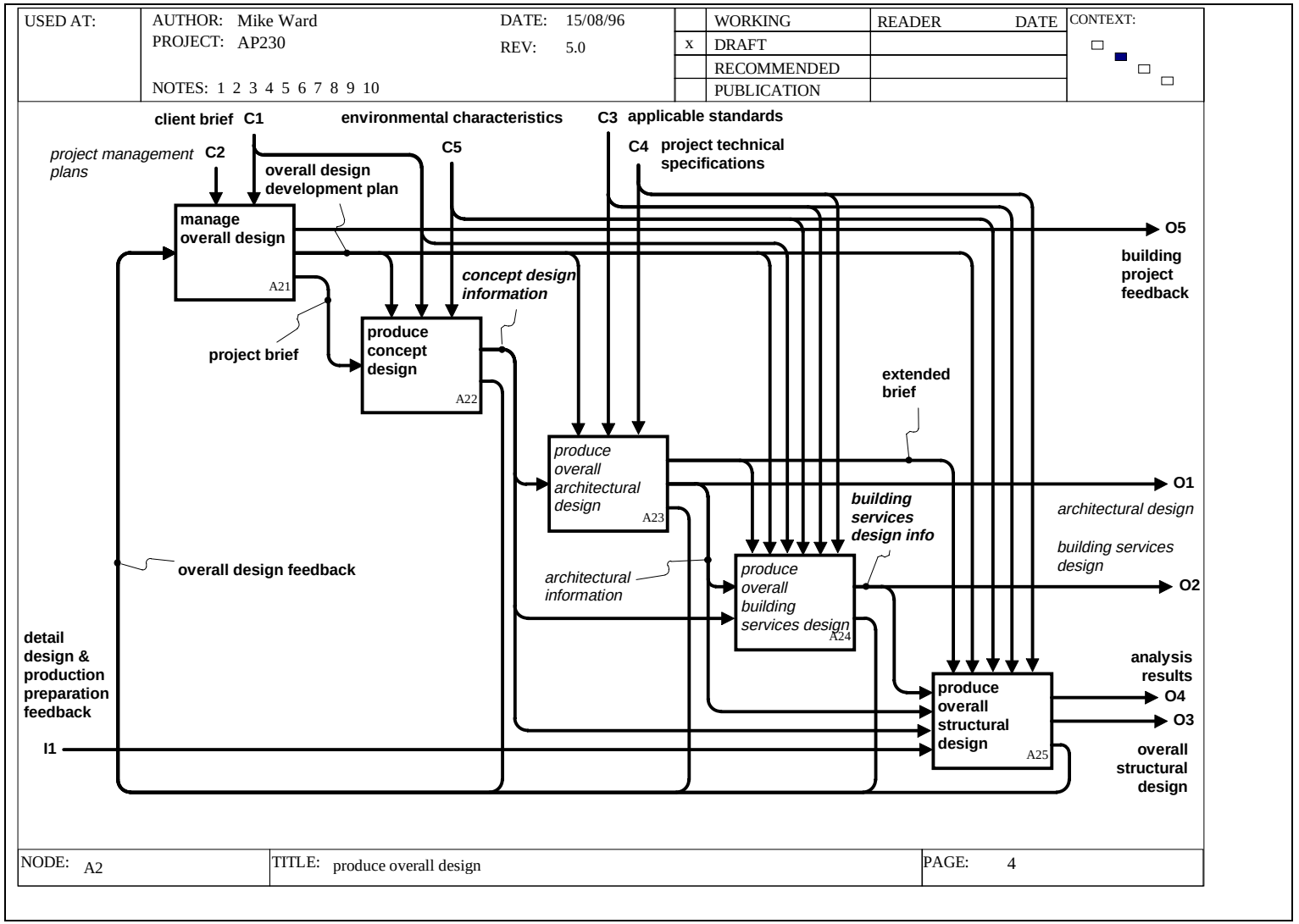

Figure F.4 - A2: Produce overall design

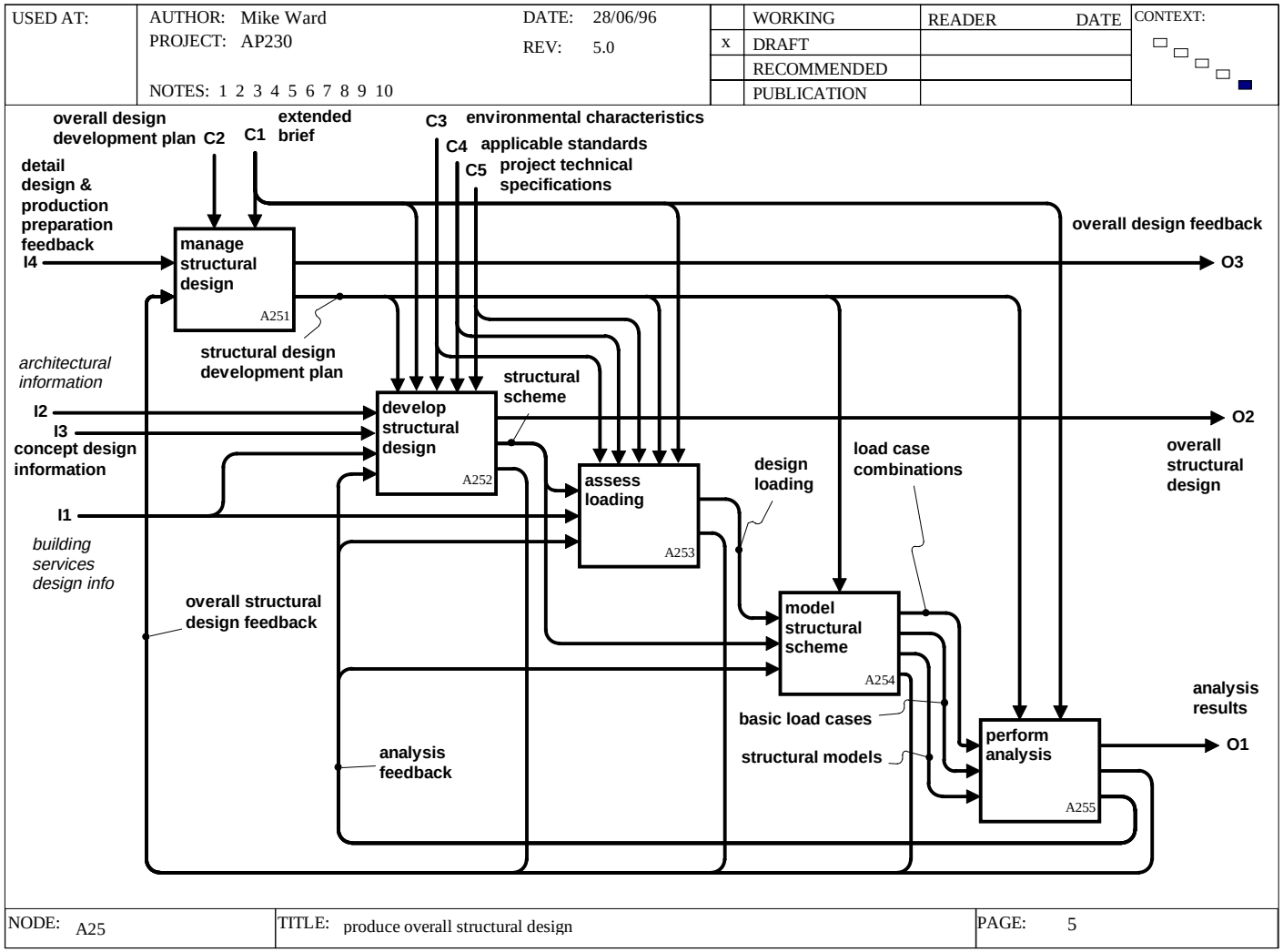

Figure F.5 - A25: Produce overall structural design

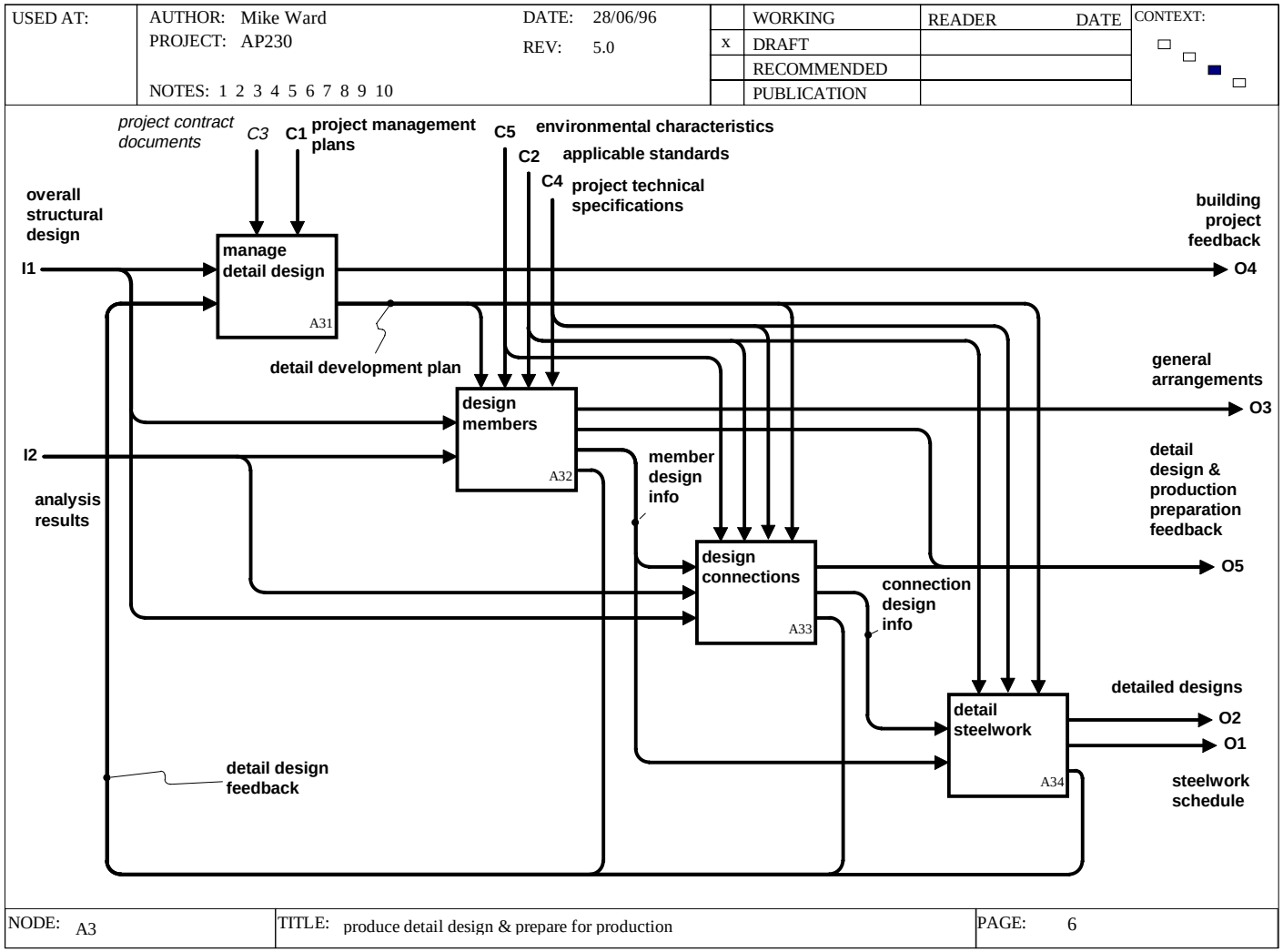

Figure F.6 - A3: Produce detail design & prepare for production

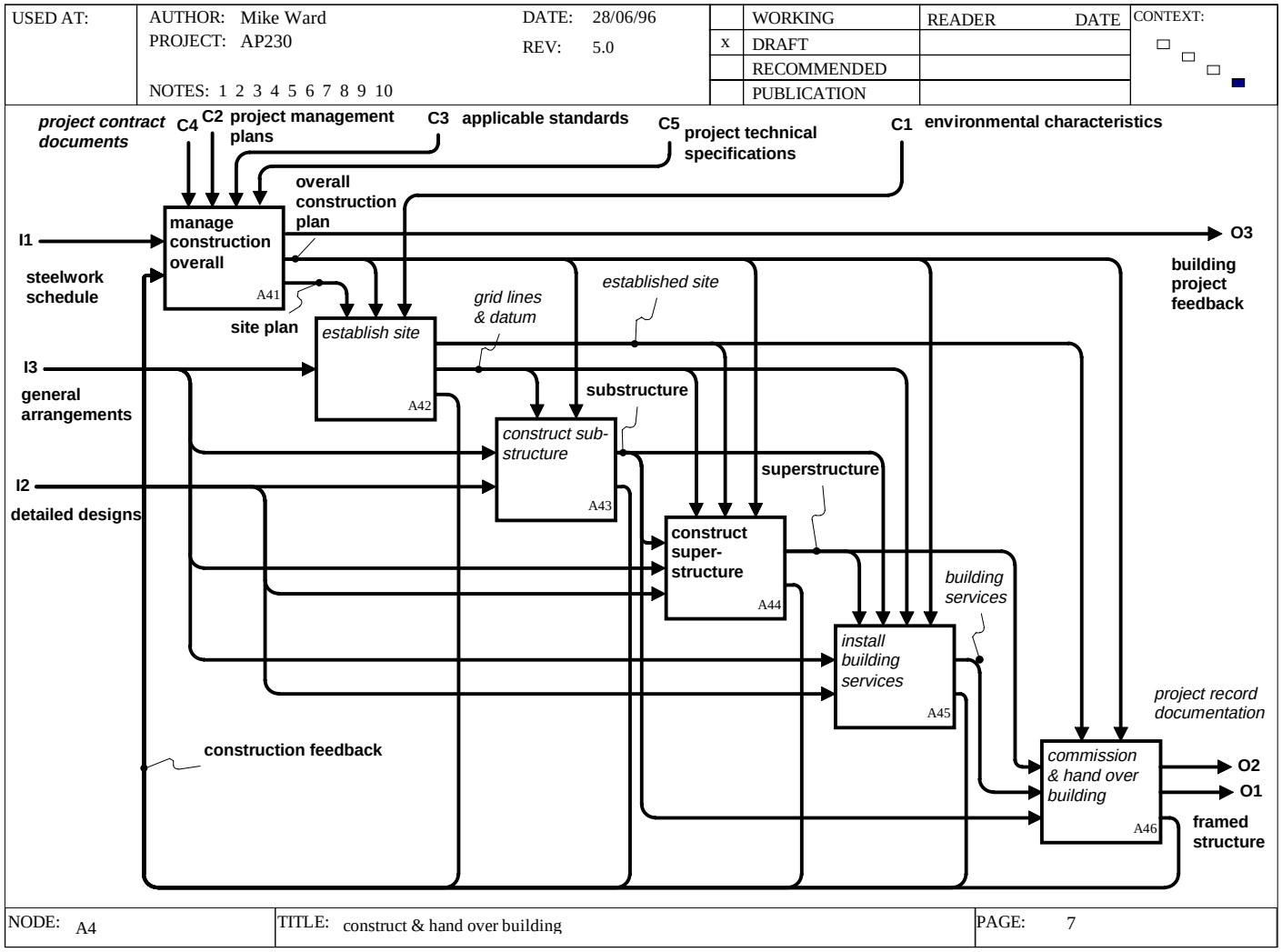

Figure F.7 - A4: Construct and hand over building

Annex G
(informative)

Application Reference Model

This annex provides the Application Reference Model for the exchange of building structural steelwork information. This ARM presents a graphical representation of the structure and constraints of the application objects specified is clause 4 of this part of ISO 10303. The ARM is independent of any implementation method.

NOTES- The application reference model is represented using the EXPRESS-G modelling language.

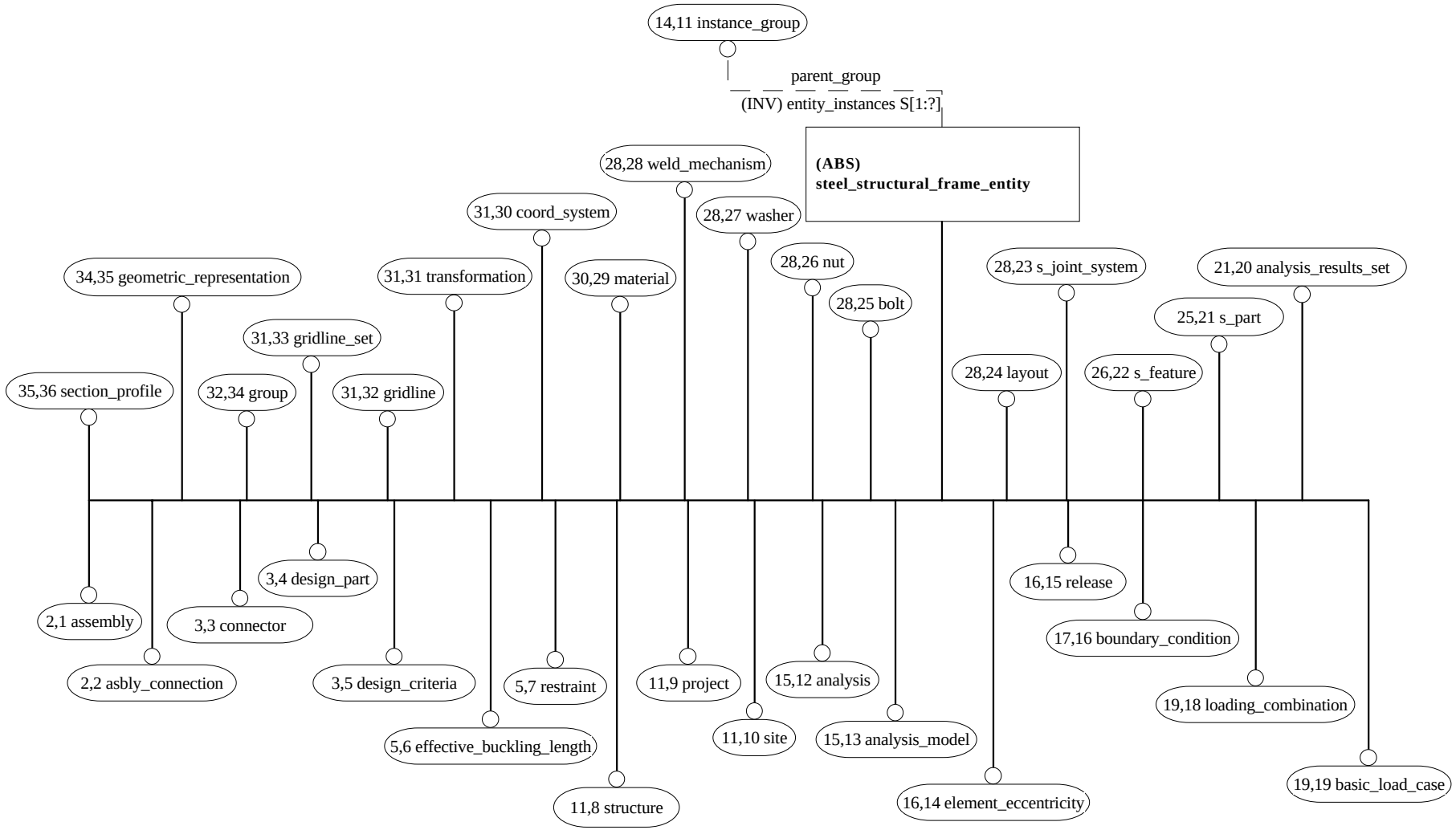

Figure G.1 - ARM diagram 1 of 40 in EXPRESS-G

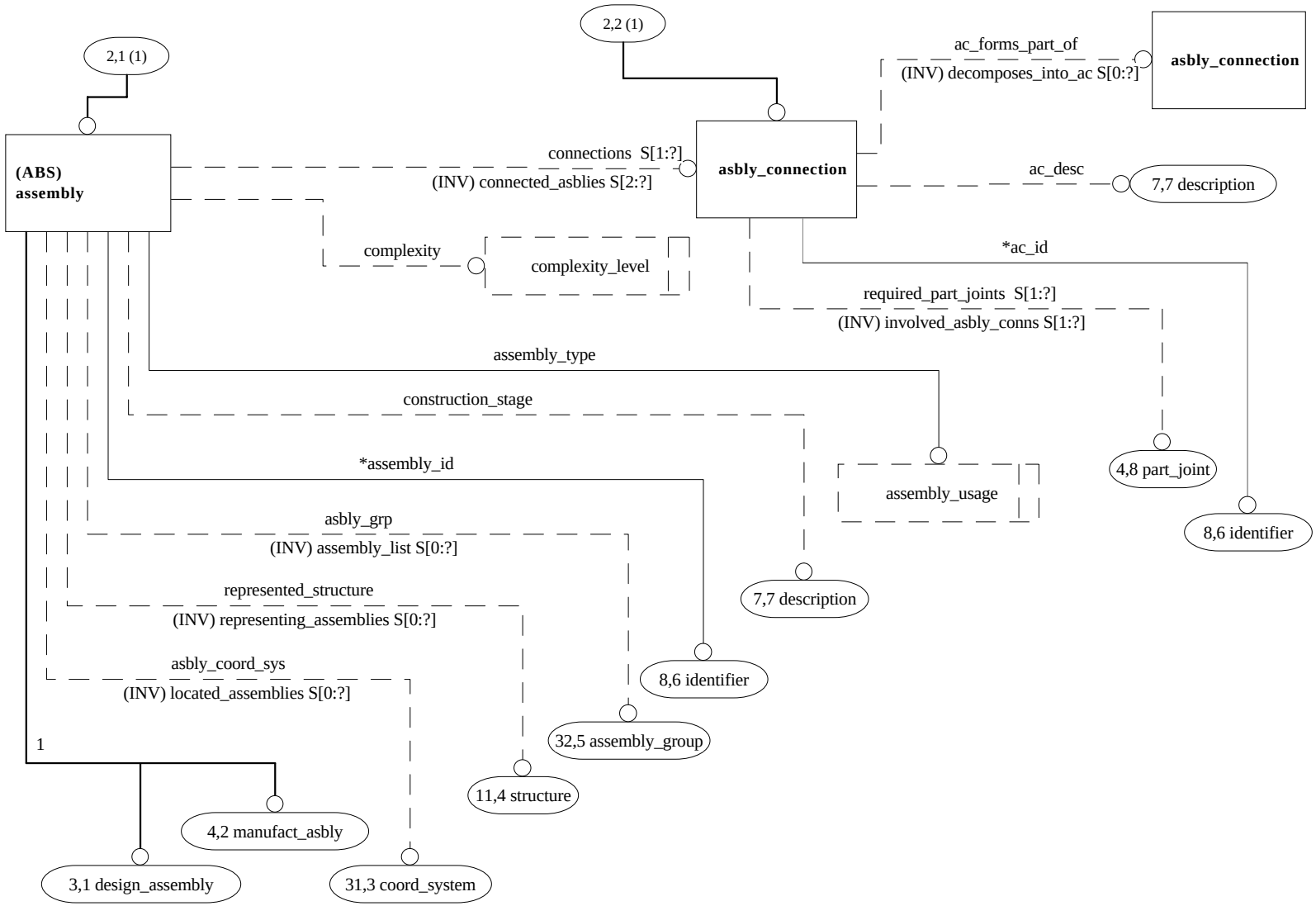

Figure G.2 - ARM diagram 2 of 40 in EXPRESS-G

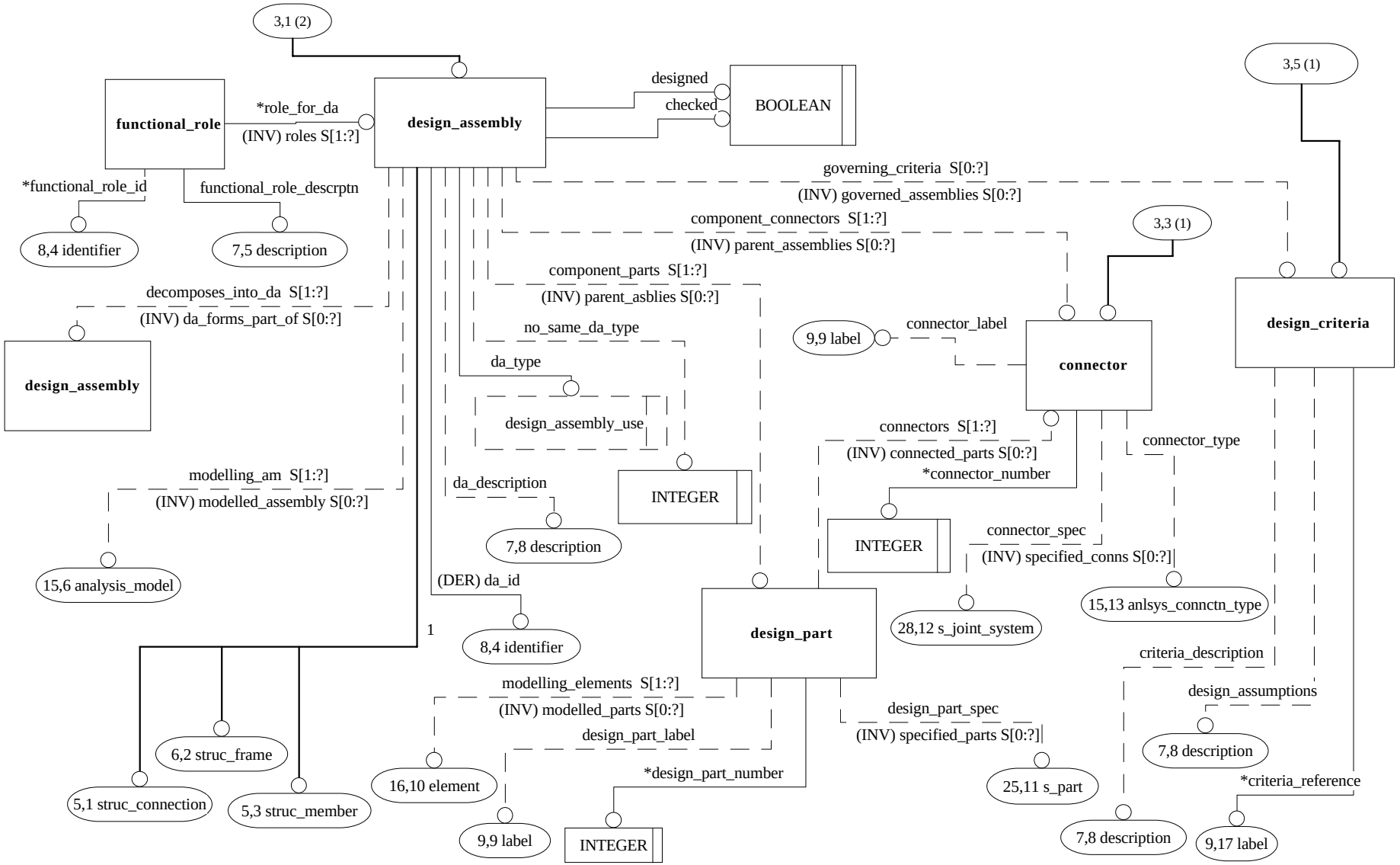

Figure G.3 - ARM diagram 3 of 40 in EXPRESS-G

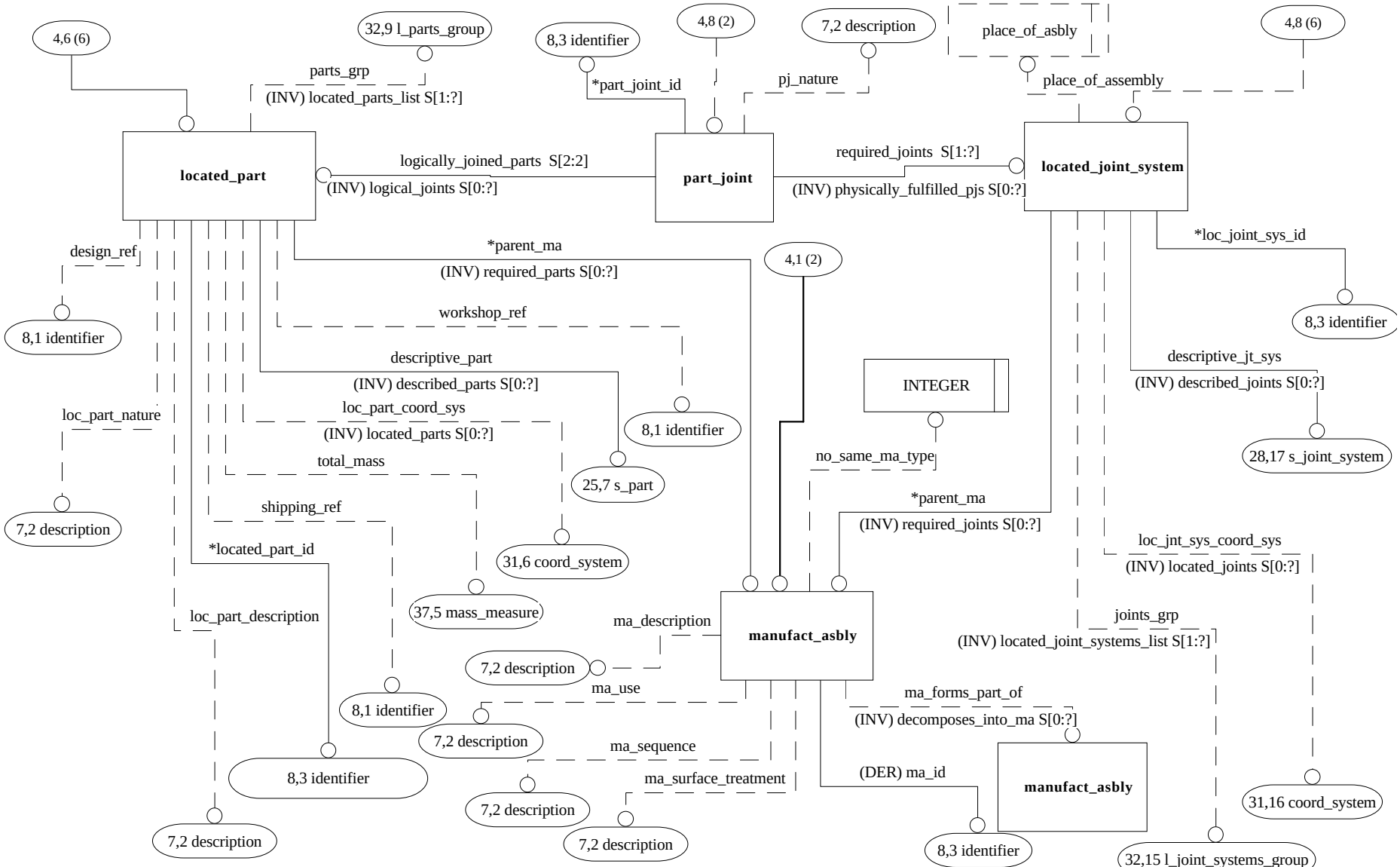

Figure G.4 - ARM diagram 4 of 40 in EXPRESS-G

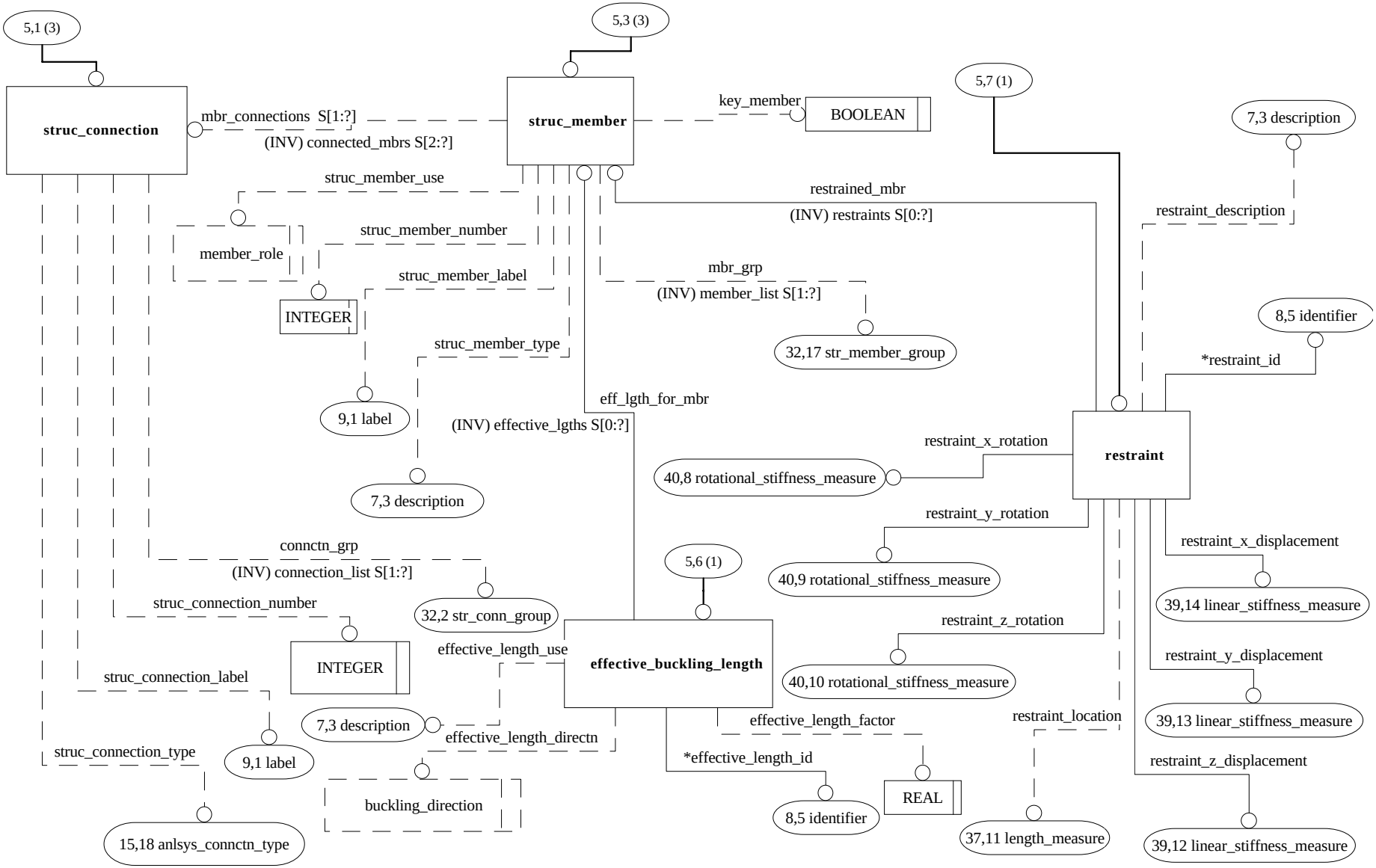

Figure G.5 - ARM diagram 5 of 40 in EXPRESS-G

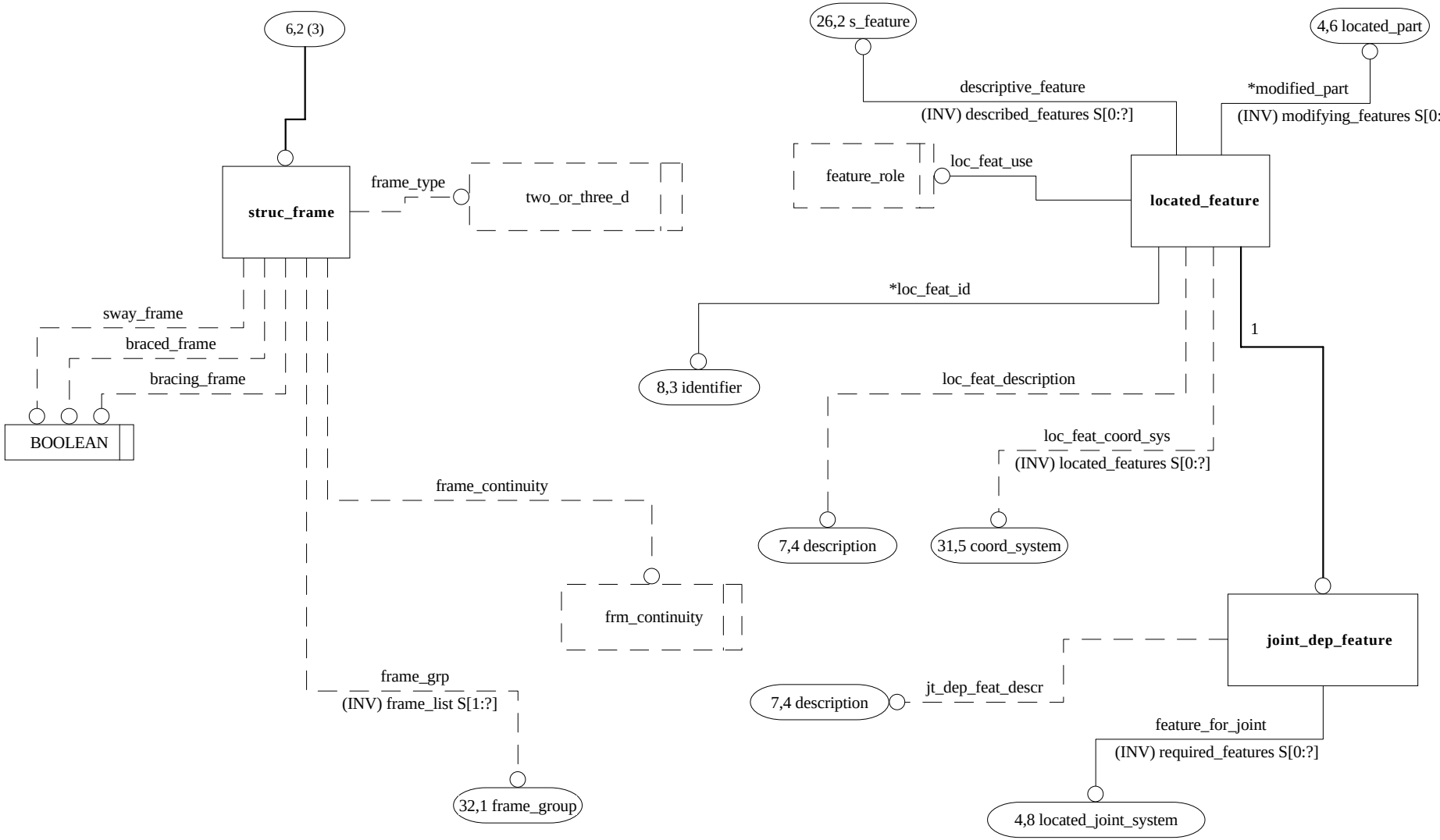

Figure G.6 - ARM diagram 6 of 40 in EXPRESS-G

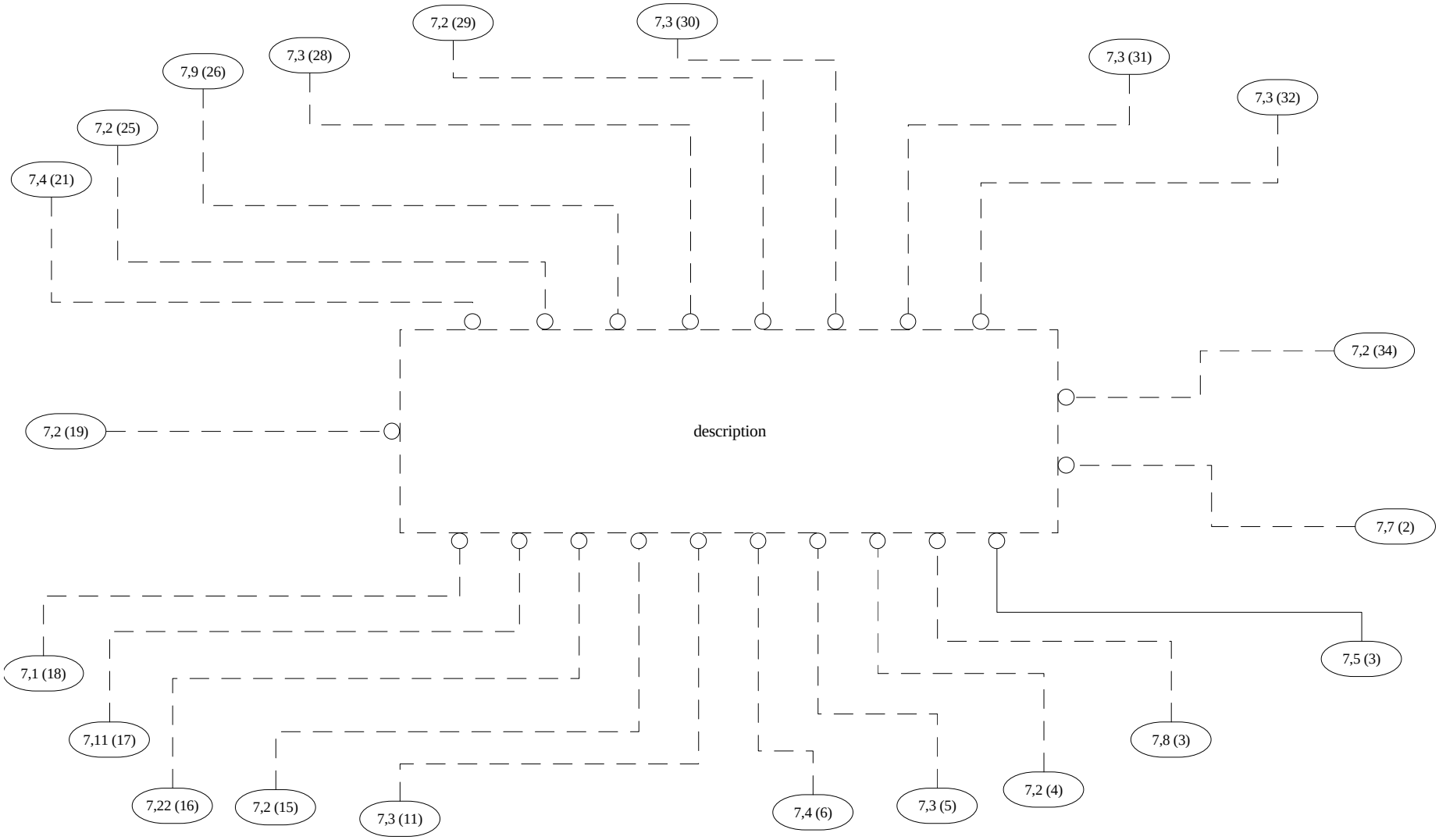

Figure G.7 - ARM diagram 7 of 40 in EXPRESS-G

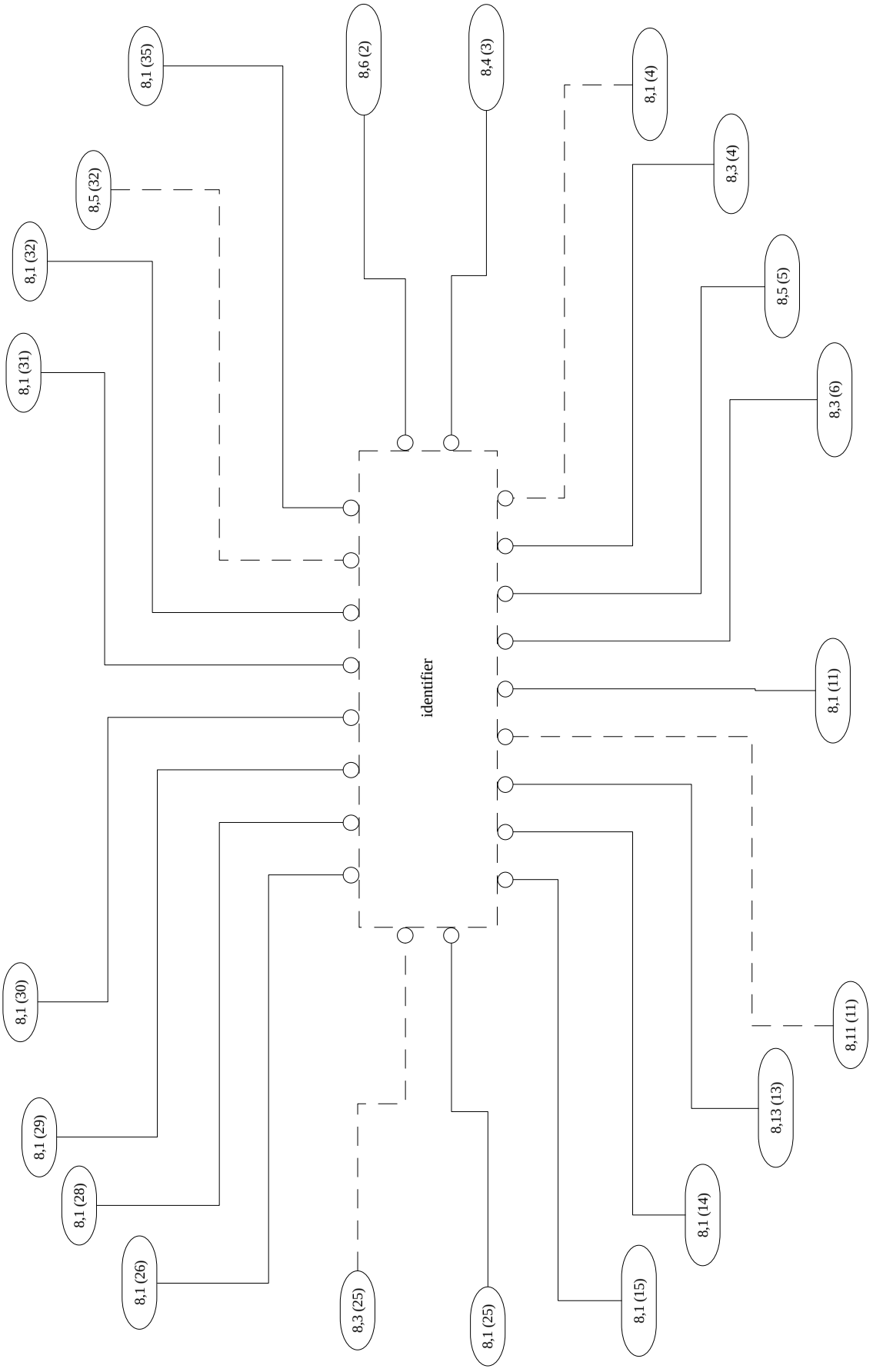

Figure G.8 - ARM diagram 8 of 40 in EXPRESS-G

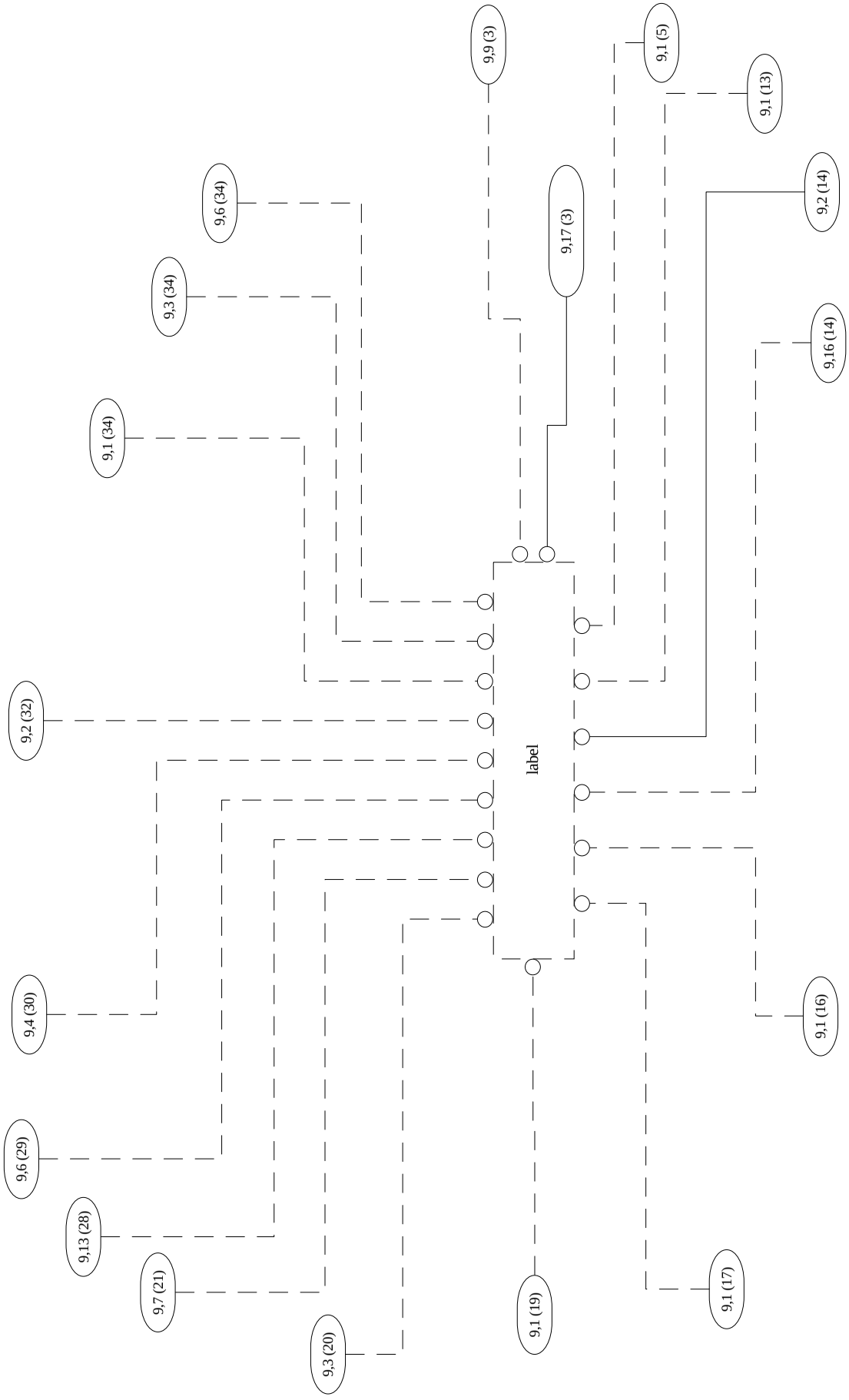

Figure G.9 - ARM diagram 9 of 40 in EXPRESS-G

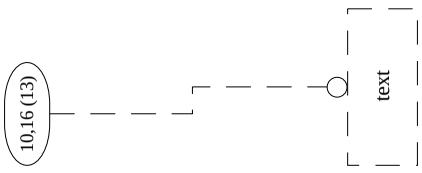

Figure G.10 - ARM diagram 10 of 40 in EXPRESS-G

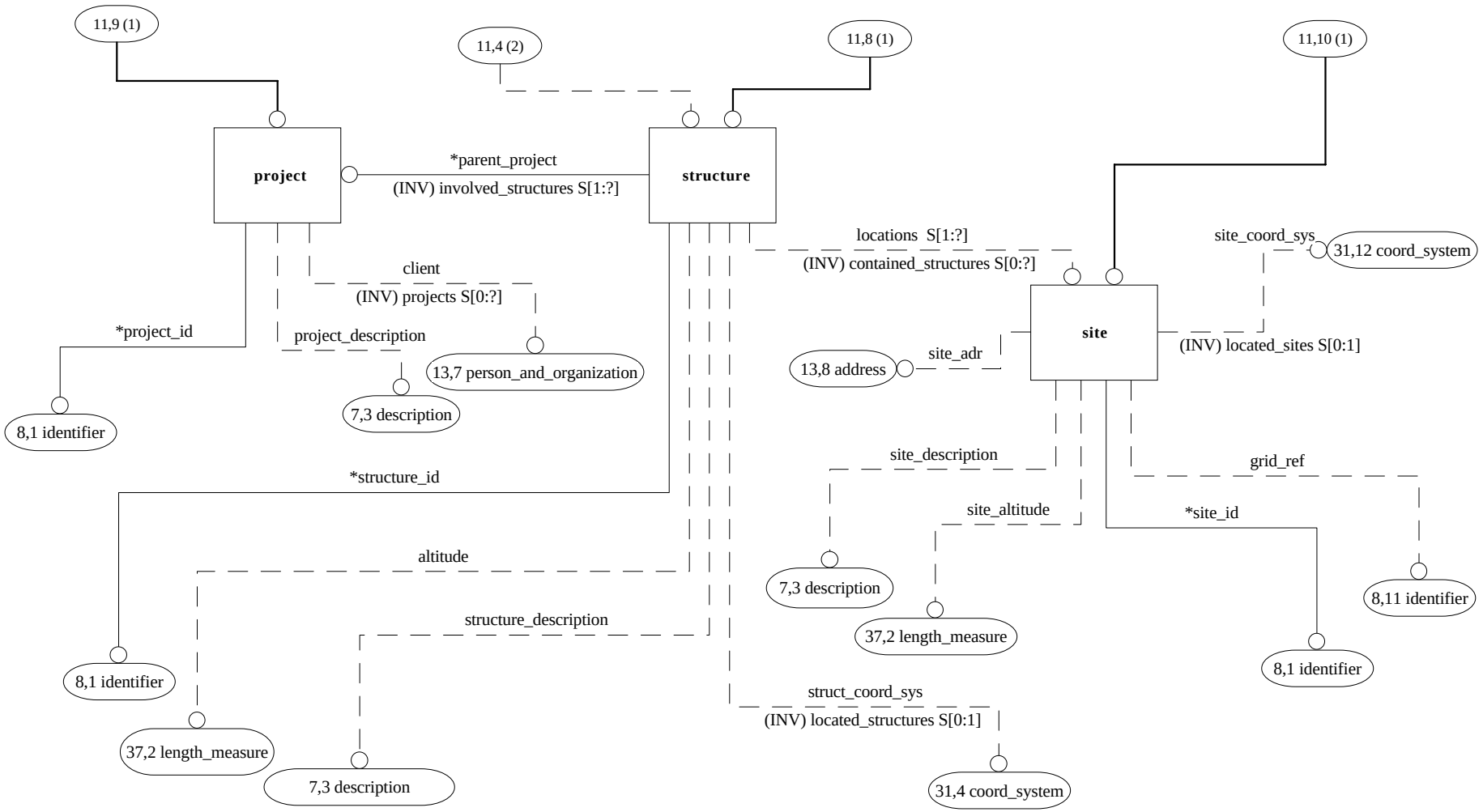

Figure G.11 - ARM diagram11 of 40 in EXPRESS-G

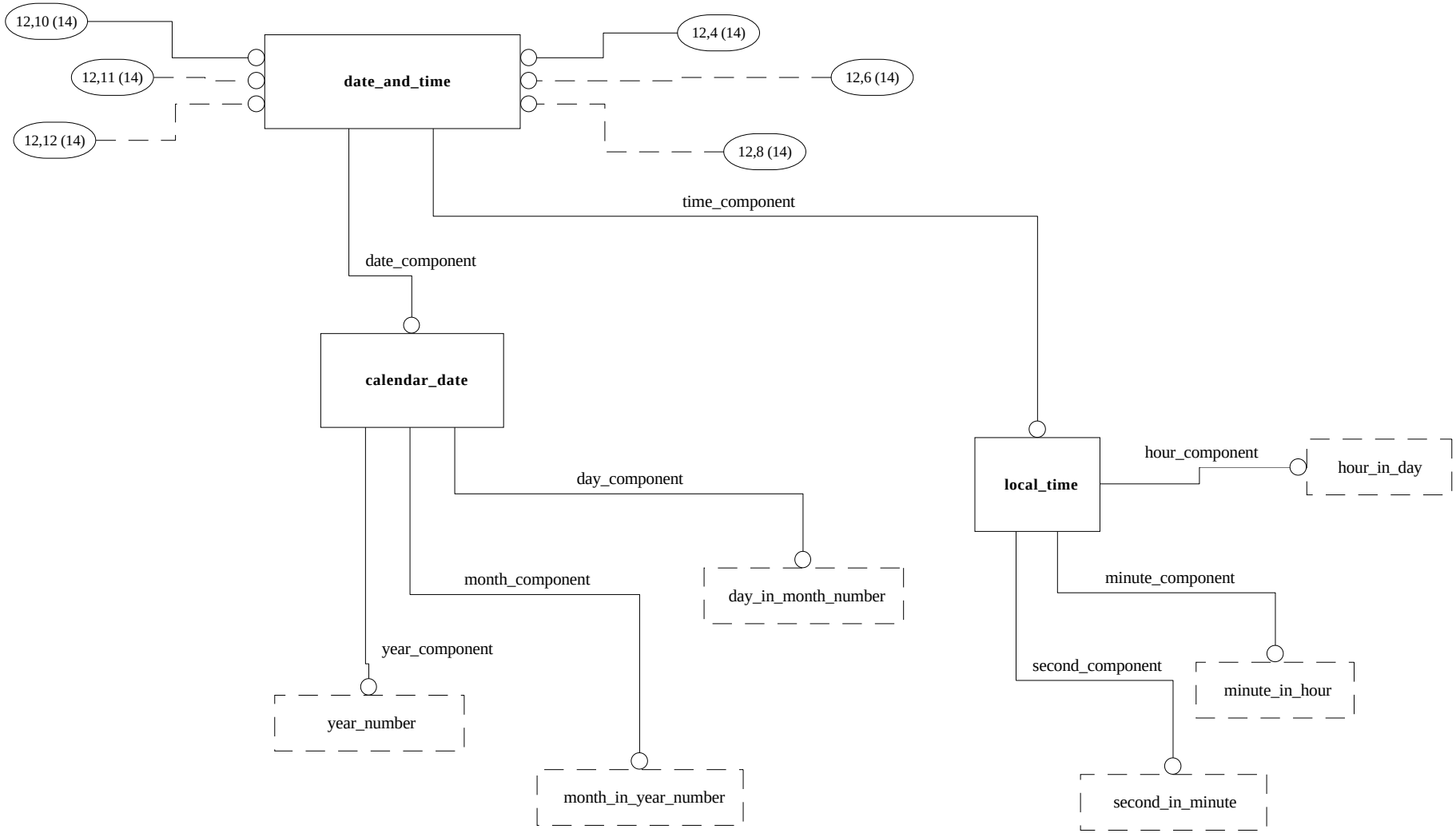

Figure G.12 - ARM diagram 12 of 40 in EXPRESS-G

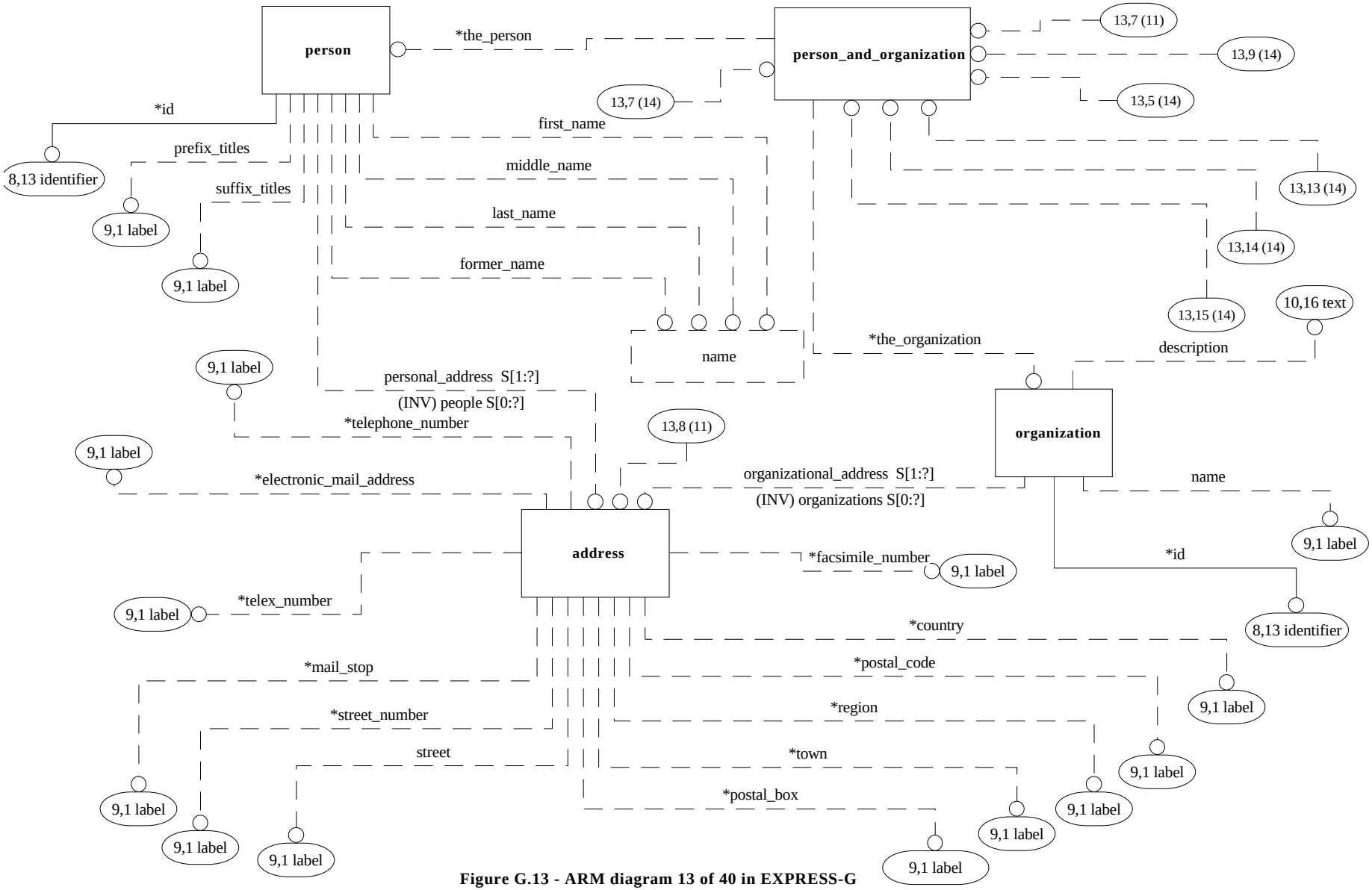

Figure G.13 - ARM diagram 13 of 40 in EXPRESS-G

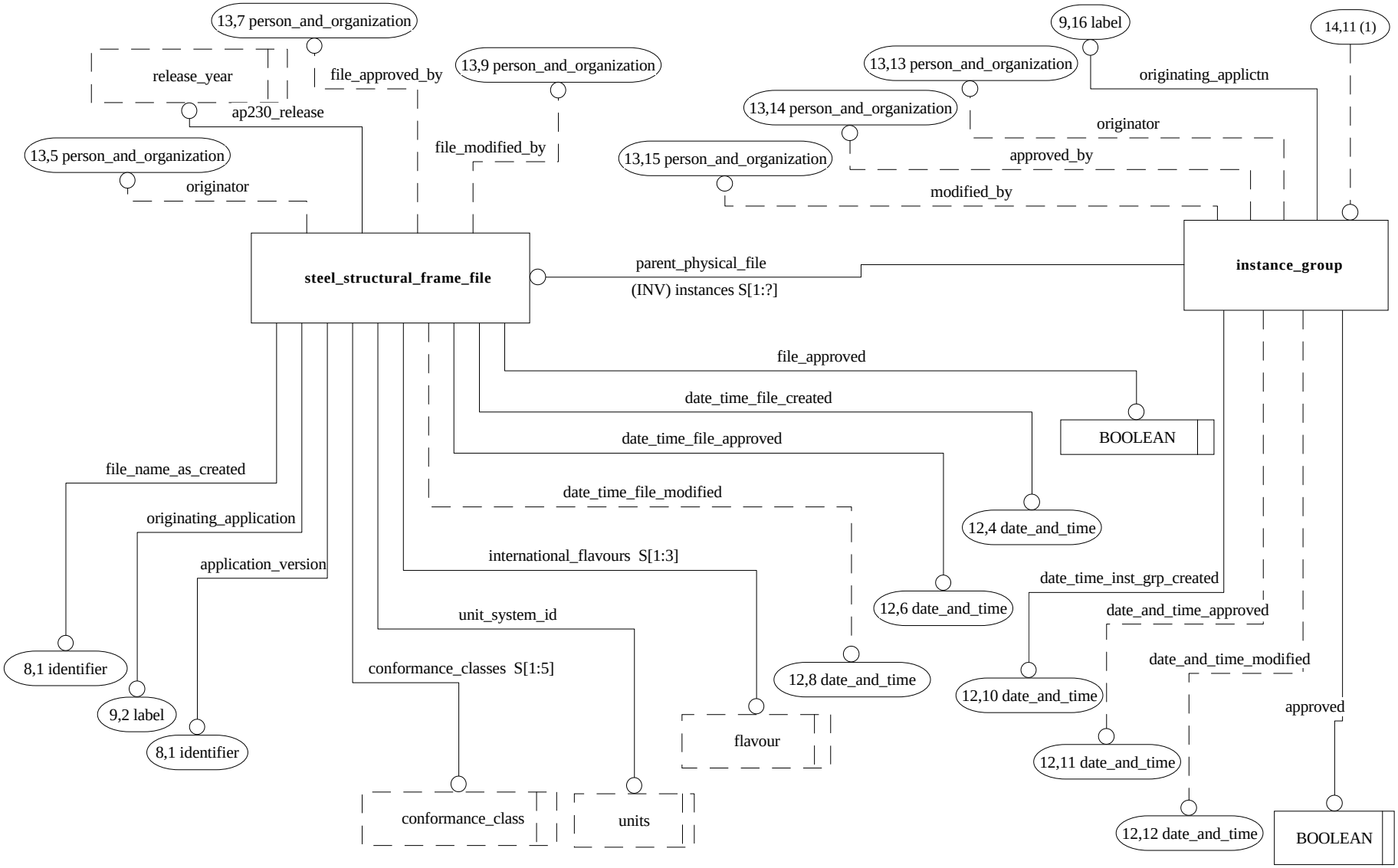

Figure G.14 - ARM diagram 14 of 40 in EXPRESS-G

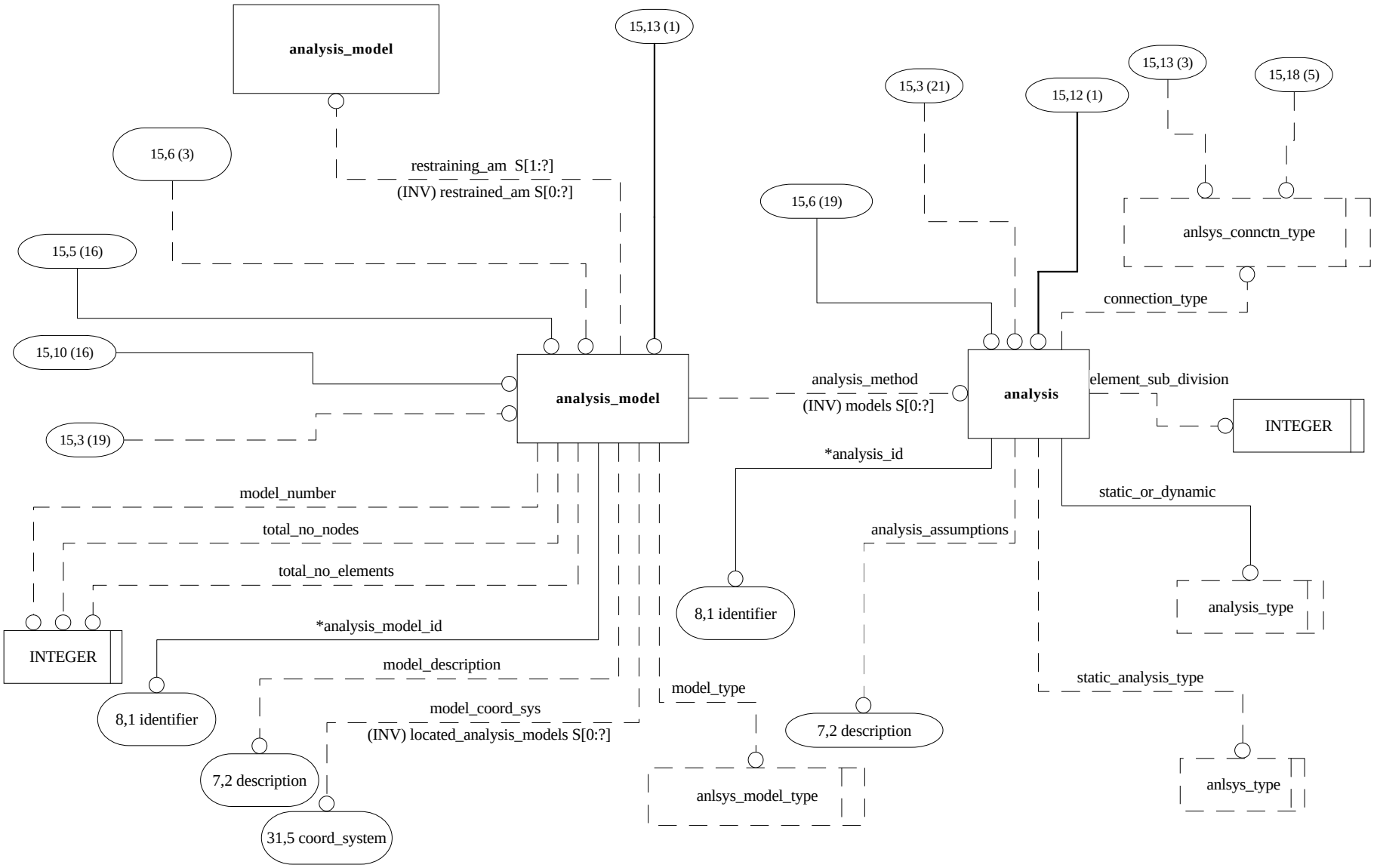

Figure G.15 - ARM diagram 15 of 40 in EXPRESS-G

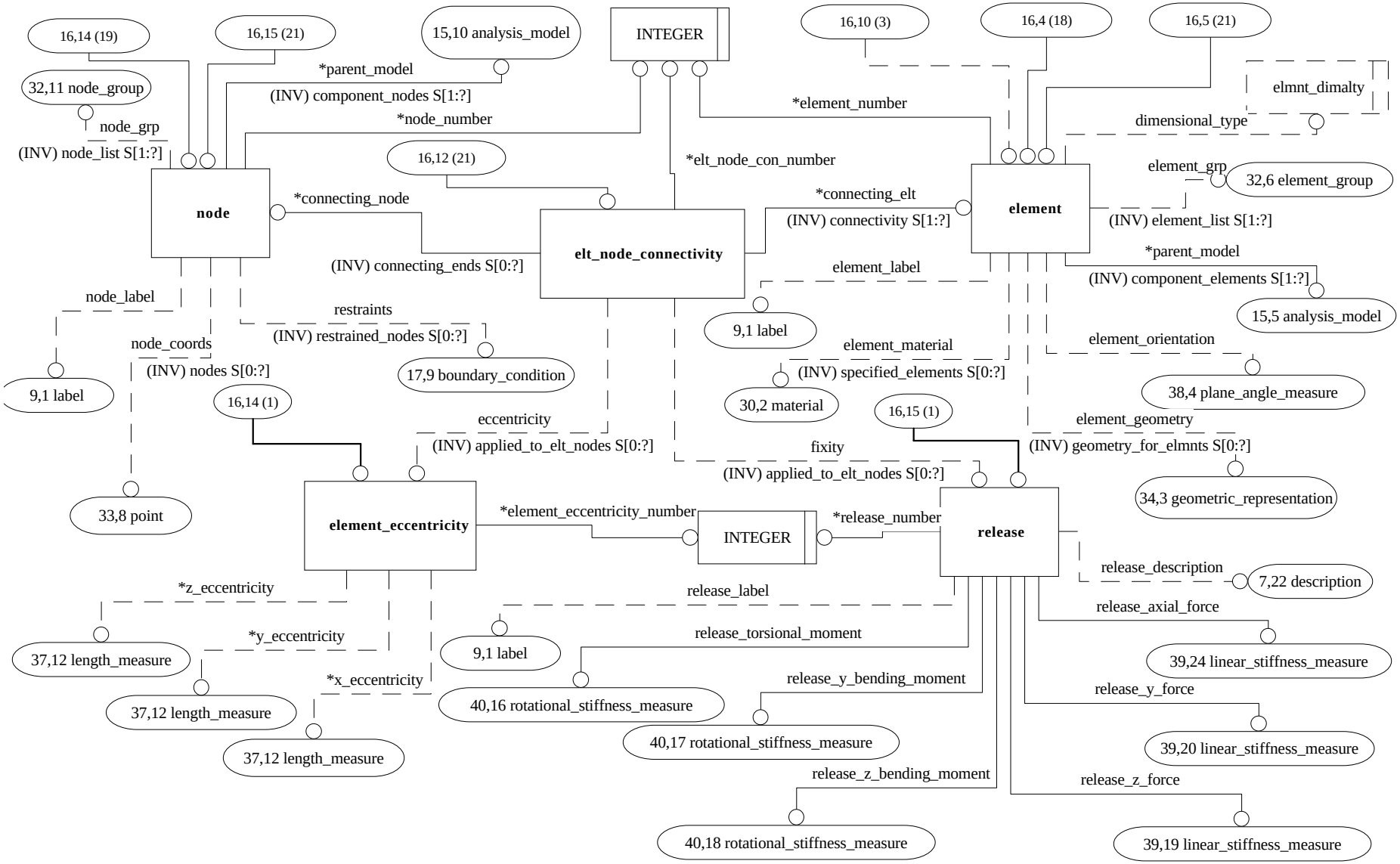

Figure G.16 - ARM diagram 16 of 40 in EXPRESS-G

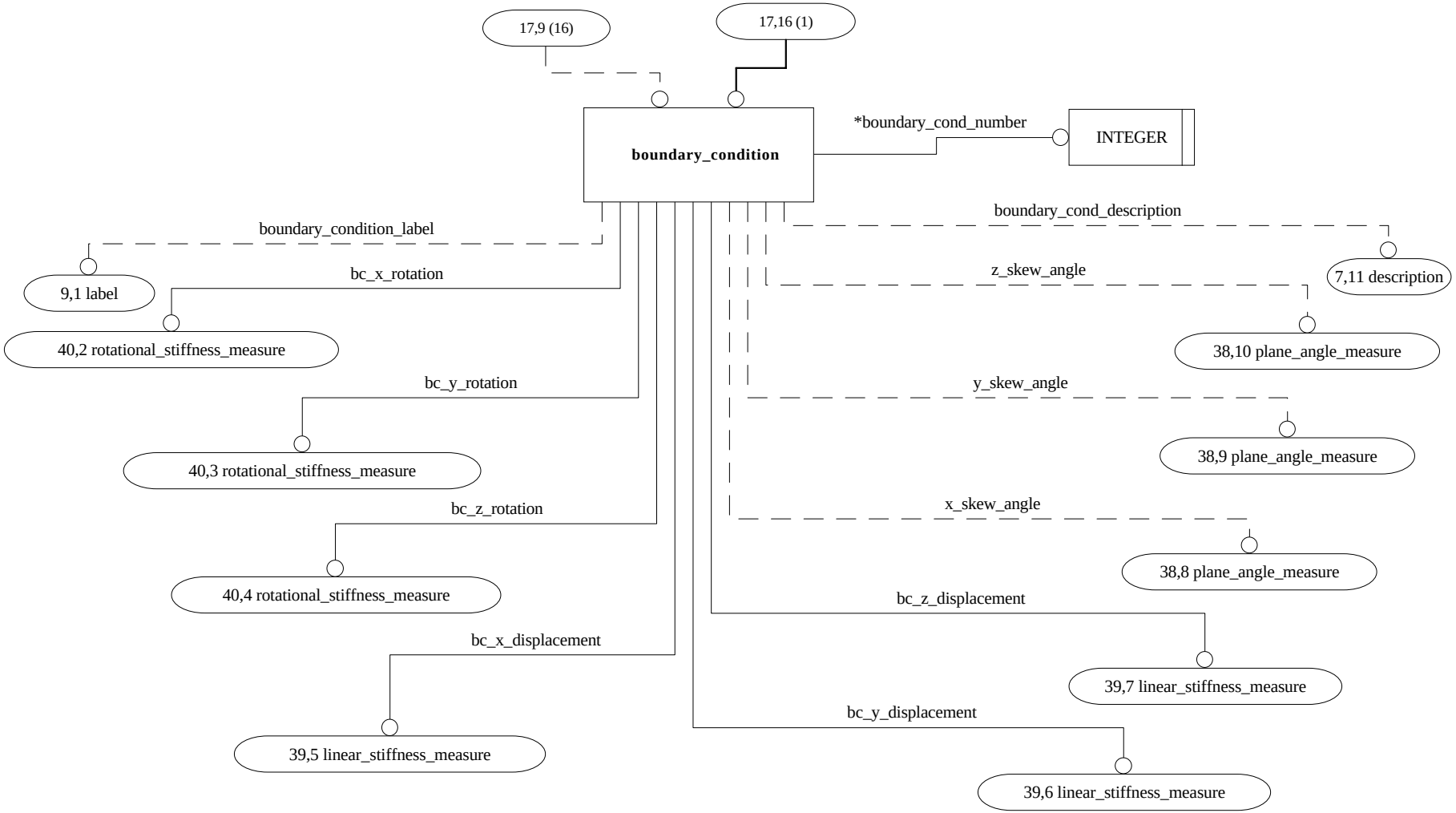

Figure G.17 - ARM diagram 17 of 40 in EXPRESS-G

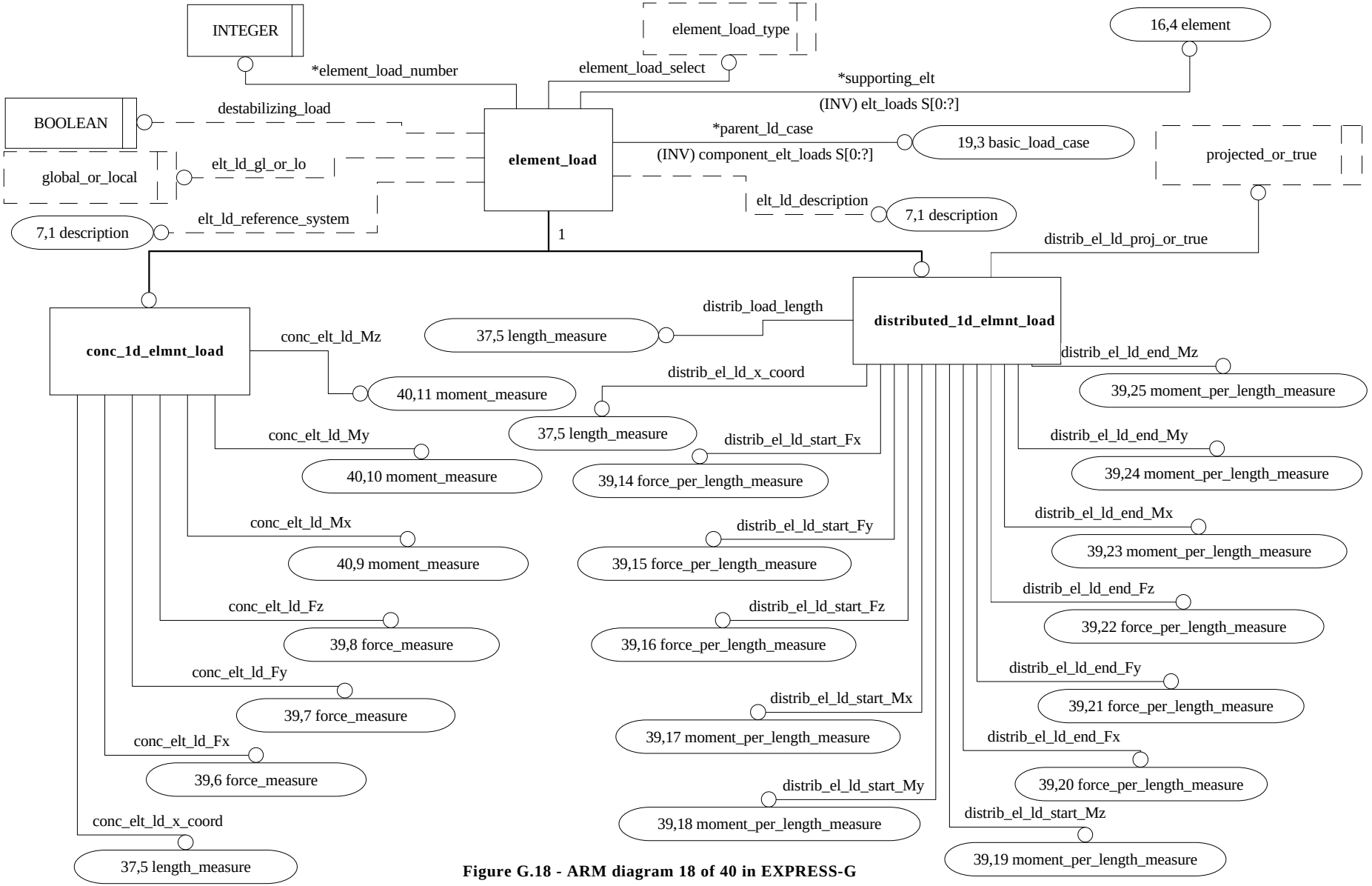

Figure G.18 - ARM diagram 18 of 40 in EXPRESS-G

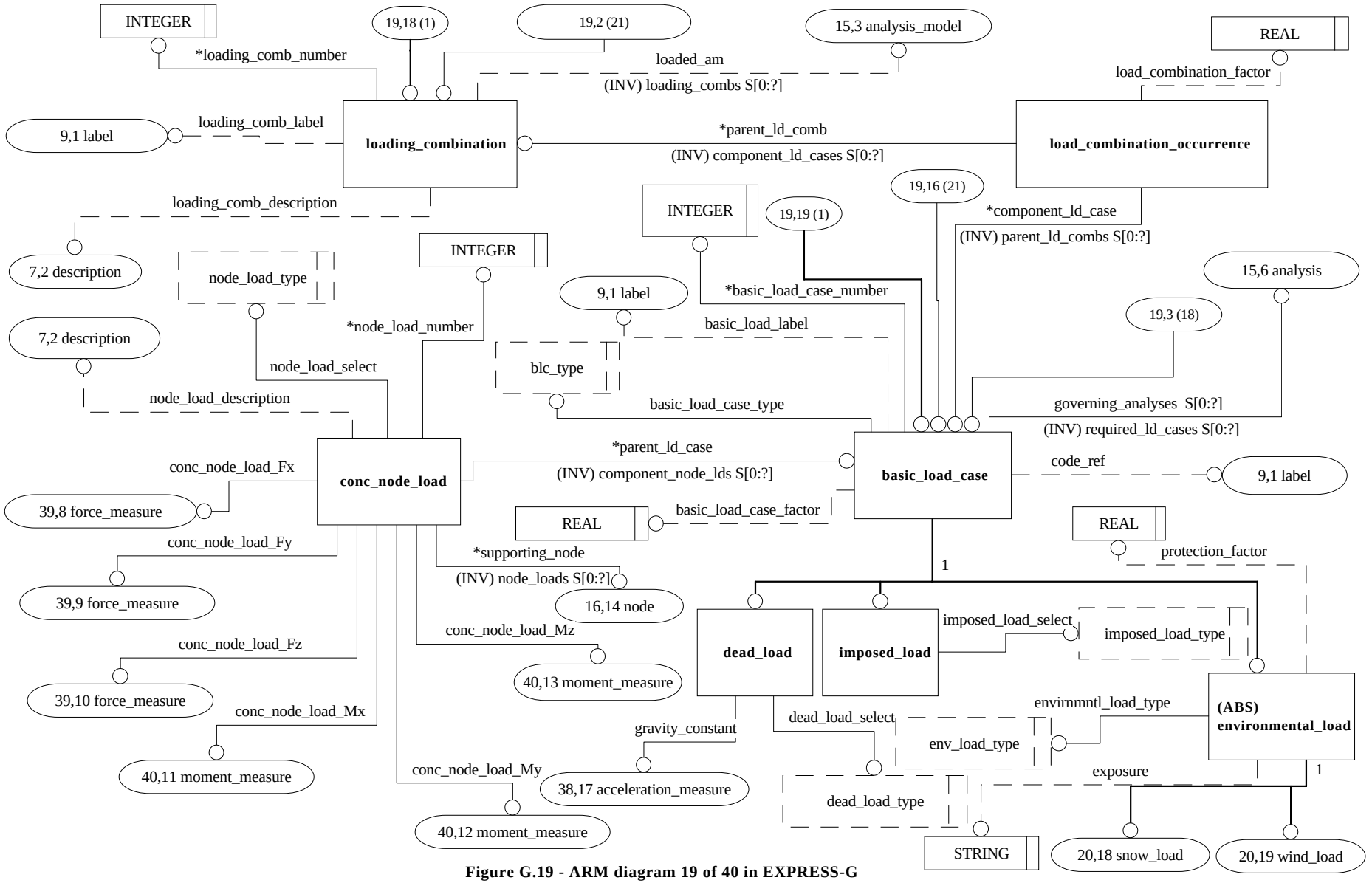

Figure G.19 - ARM diagram 19 of 40 in EXPRESS-G

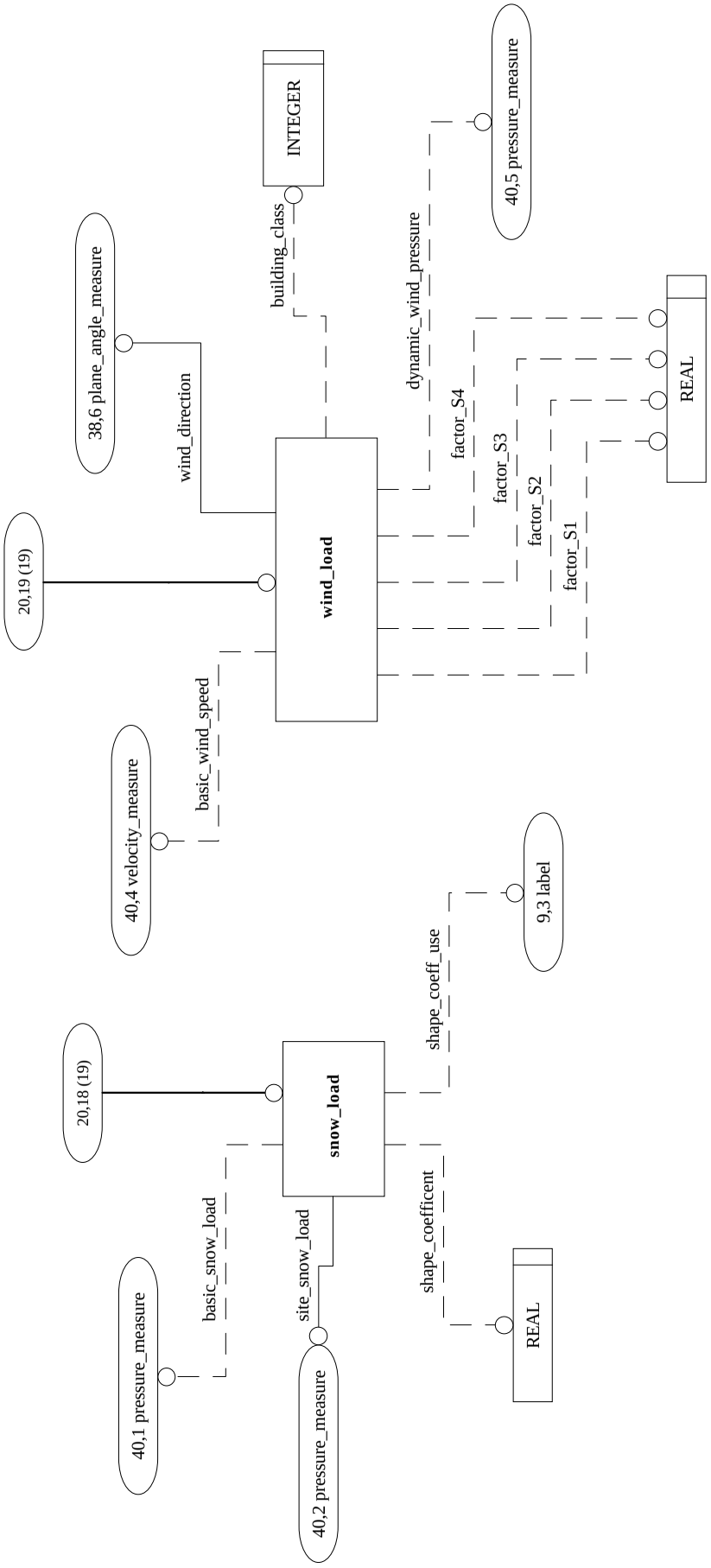

Figure G.20 - ARM diagram 20 of 40 in EXPRESS-G

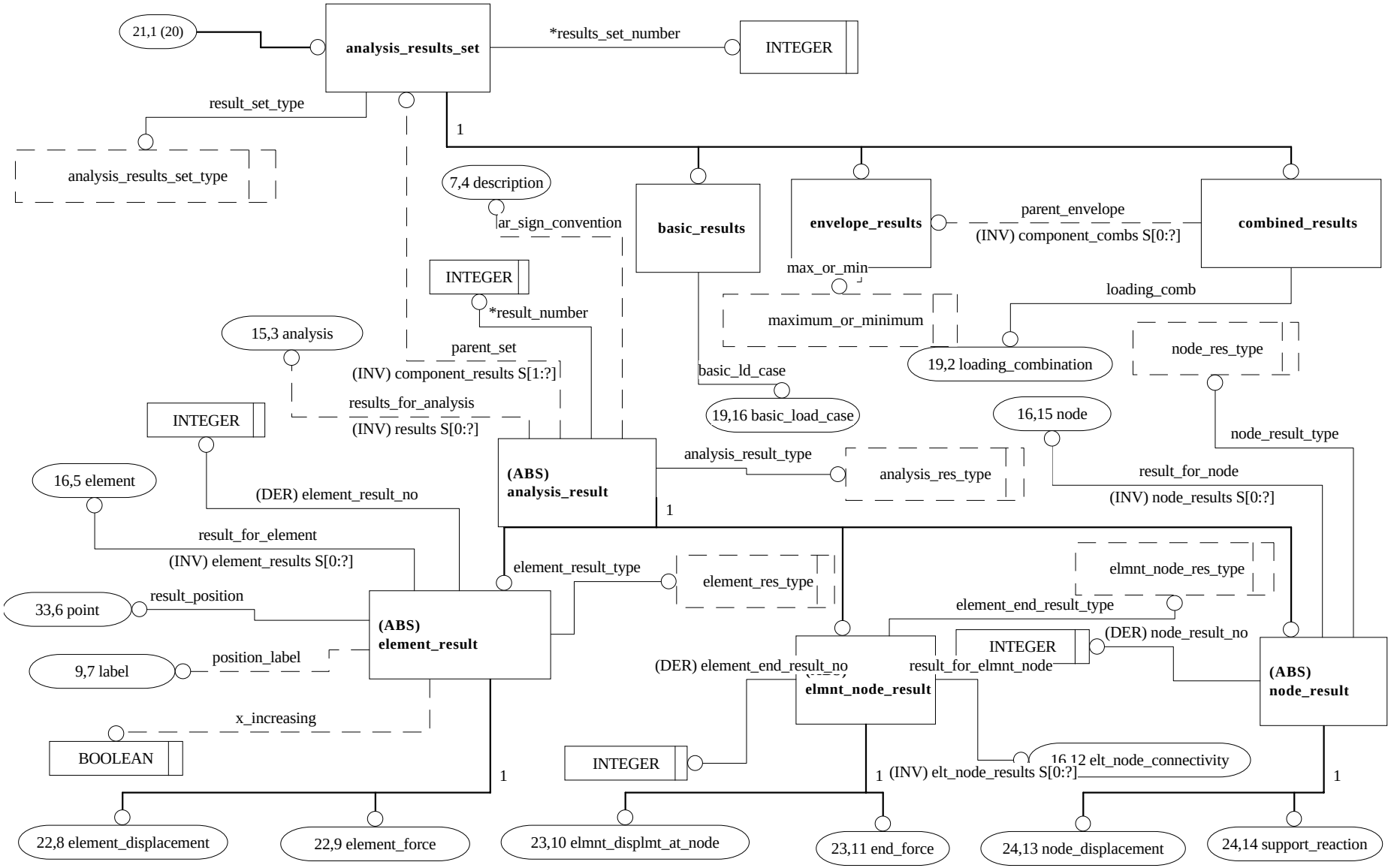

Figure G.21 - ARM diagram 21 of 40 in EXPRESS-G

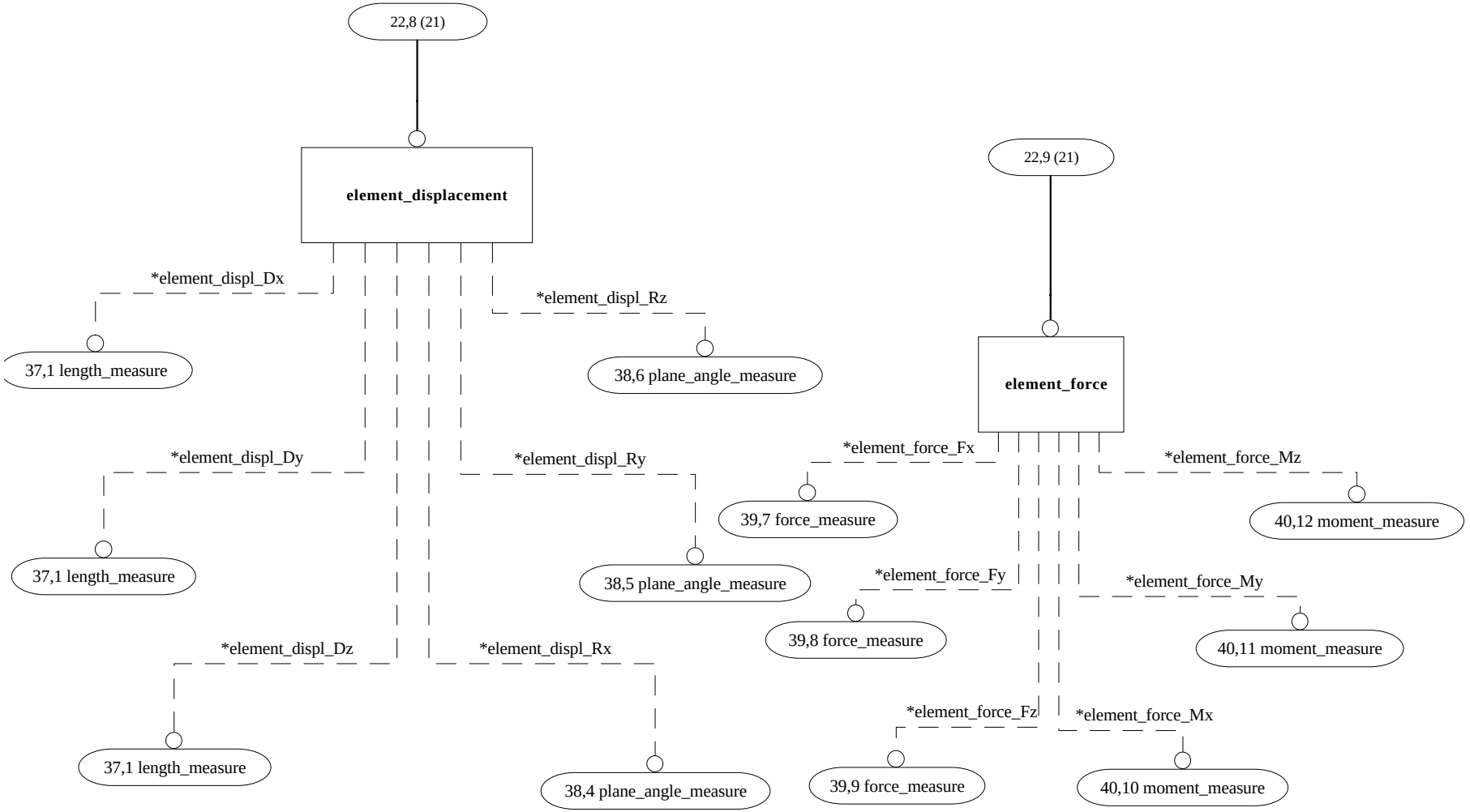

Figure G.22 - ARM diagram 22 of 40 in EXPRESS-G

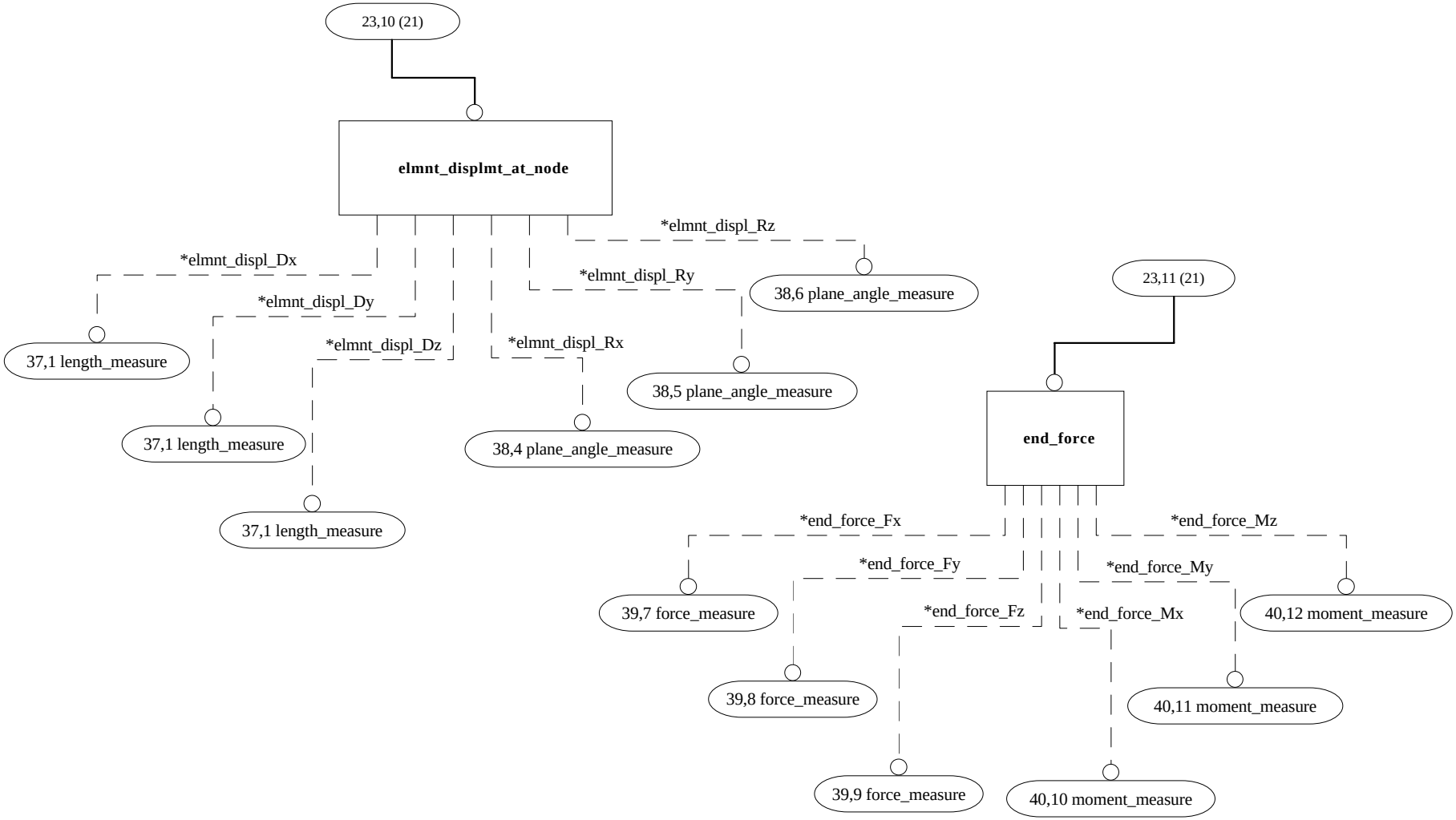

Figure G.23 - ARM diagram 23 of 40 in EXPRESS-G

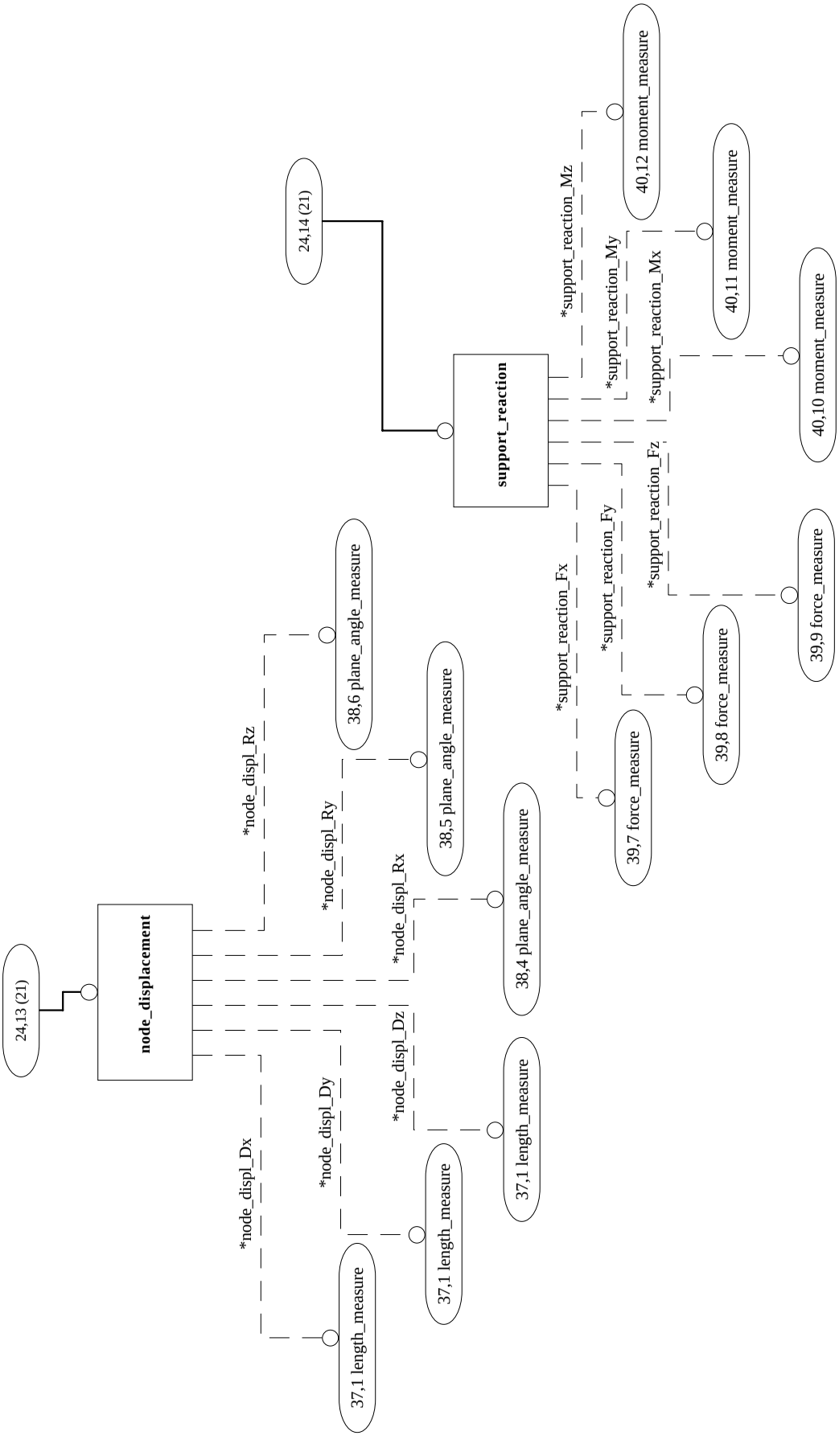

Figure G.24 - ARM diagram 24 of 40 in EXPRESS-G

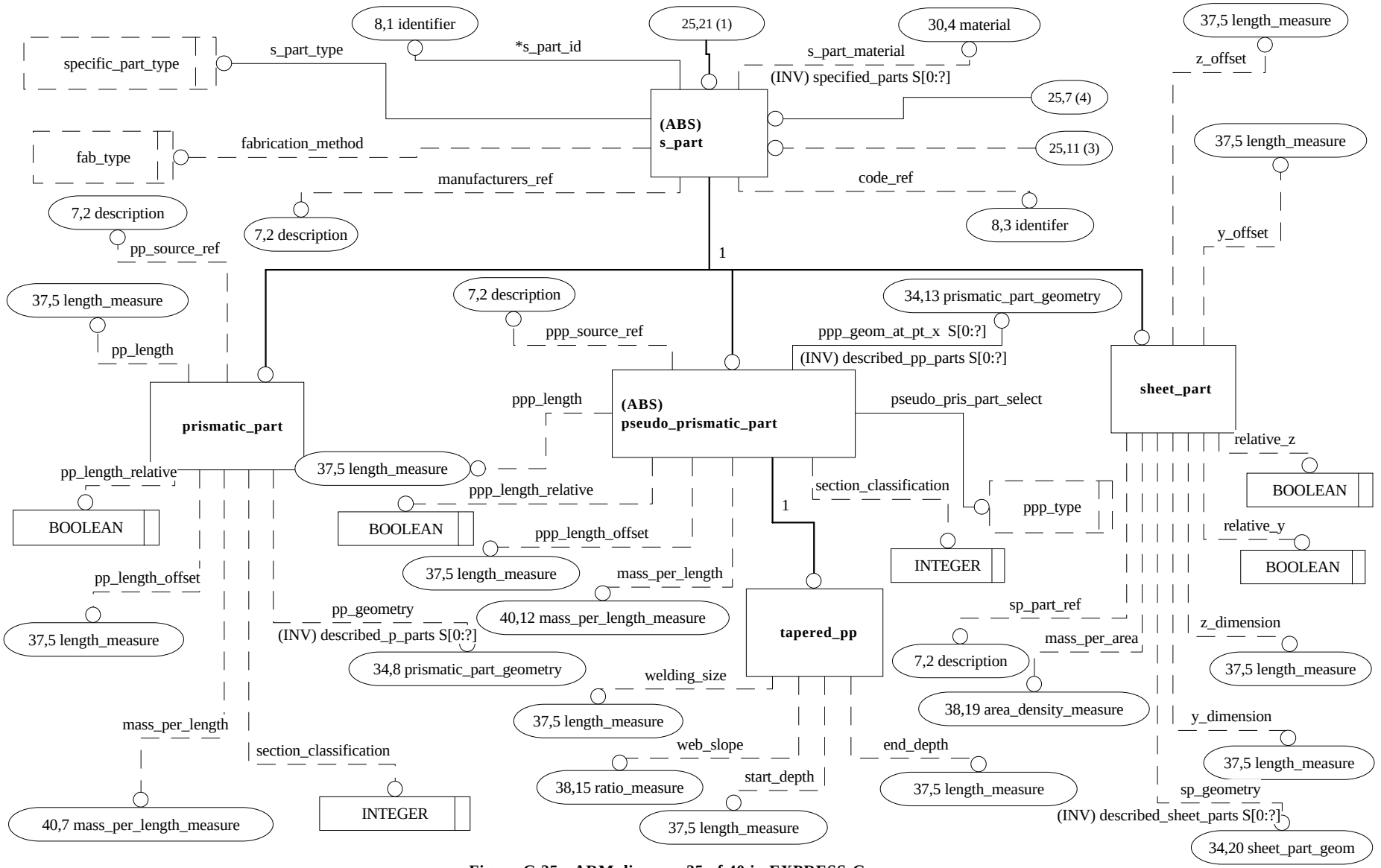

Figure G.25 - ARM diagram 25 of 40 in EXPRESS-G

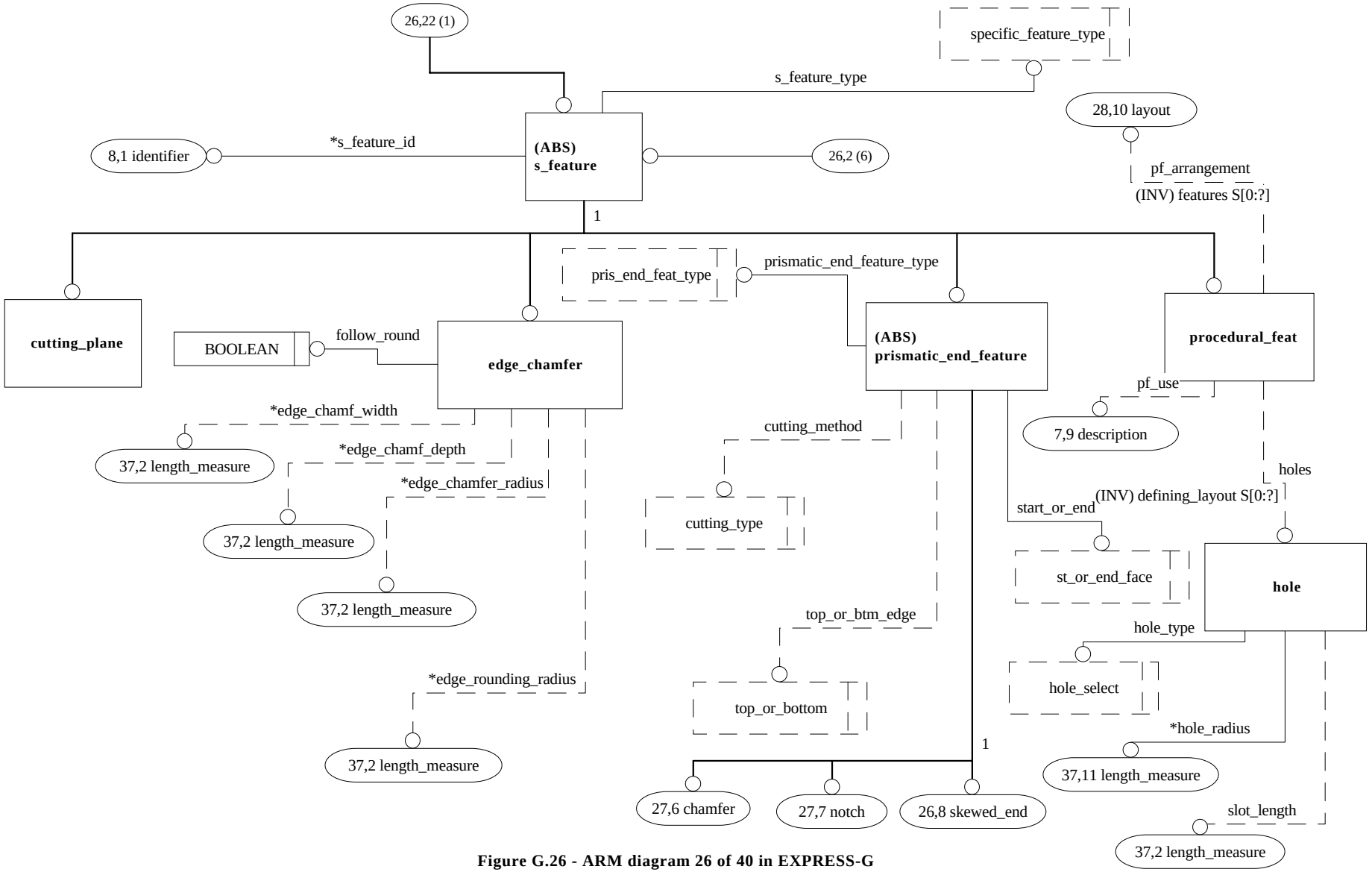

Figure G.26 - ARM diagram 26 of 40 in EXPRESS-G

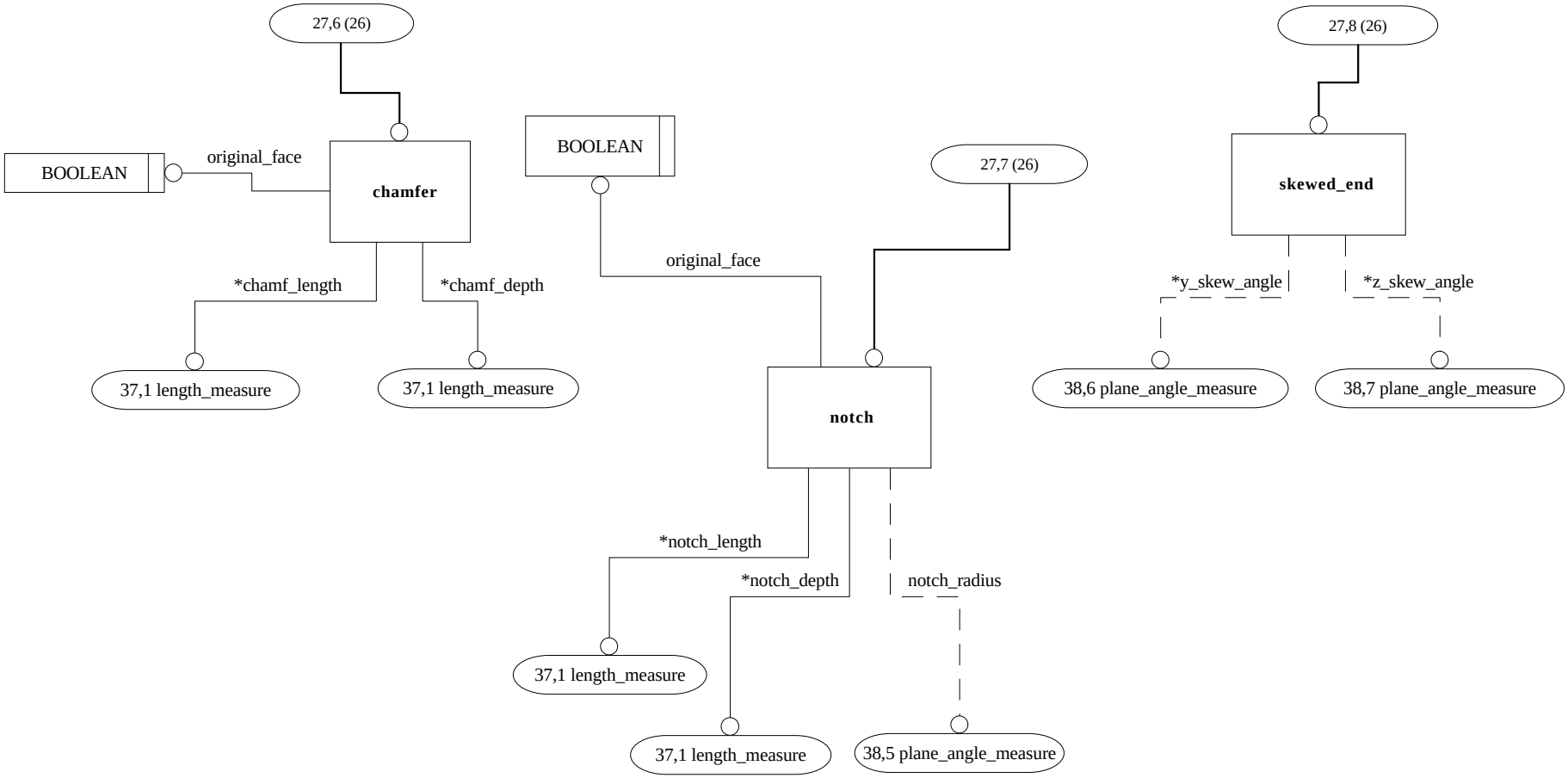

Figure G.27 - ARM diagram 27 of 40 in EXPRESS-G

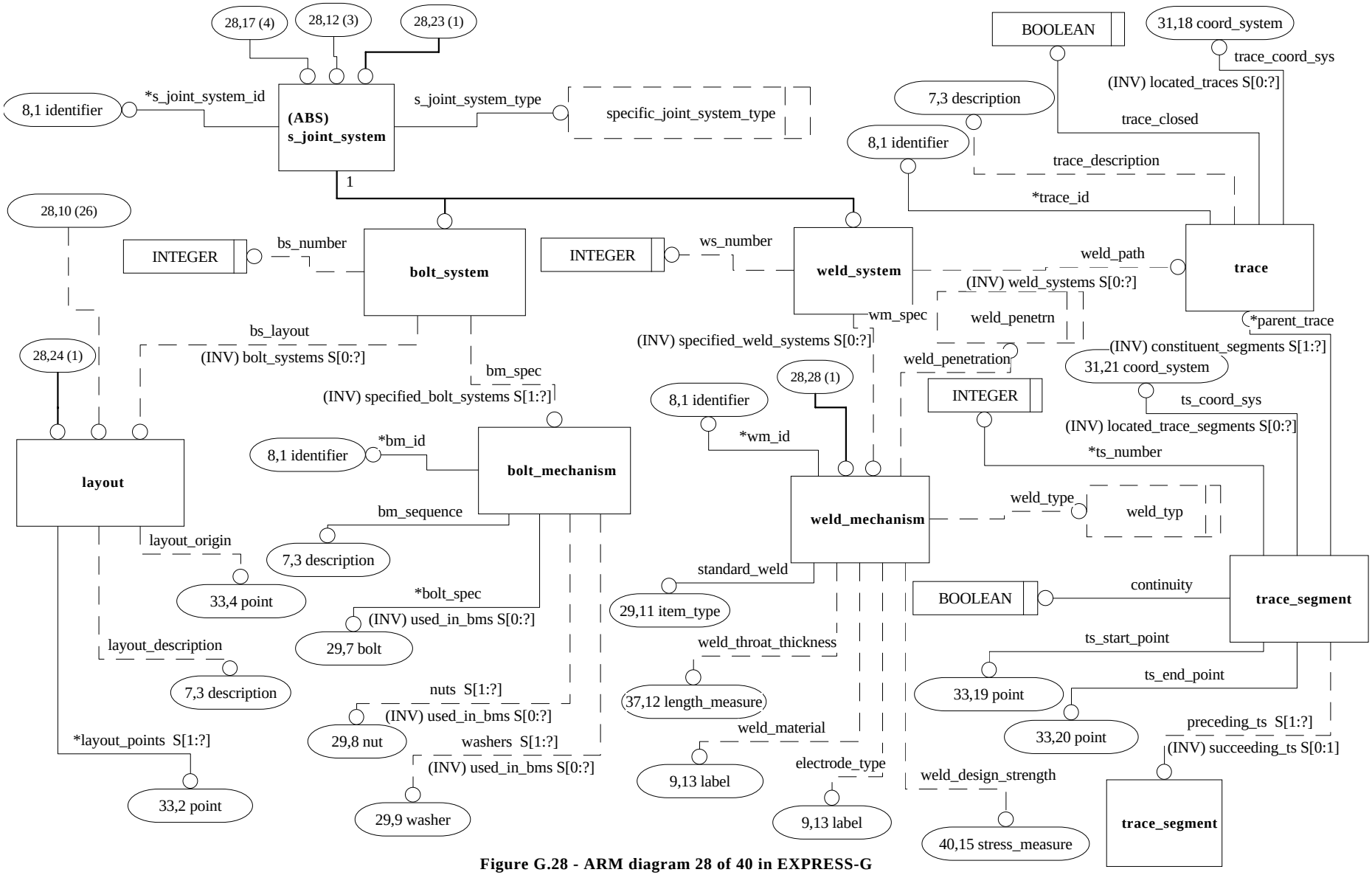

Figure G.28 - ARM diagram 28 of 40 in EXPRESS-G

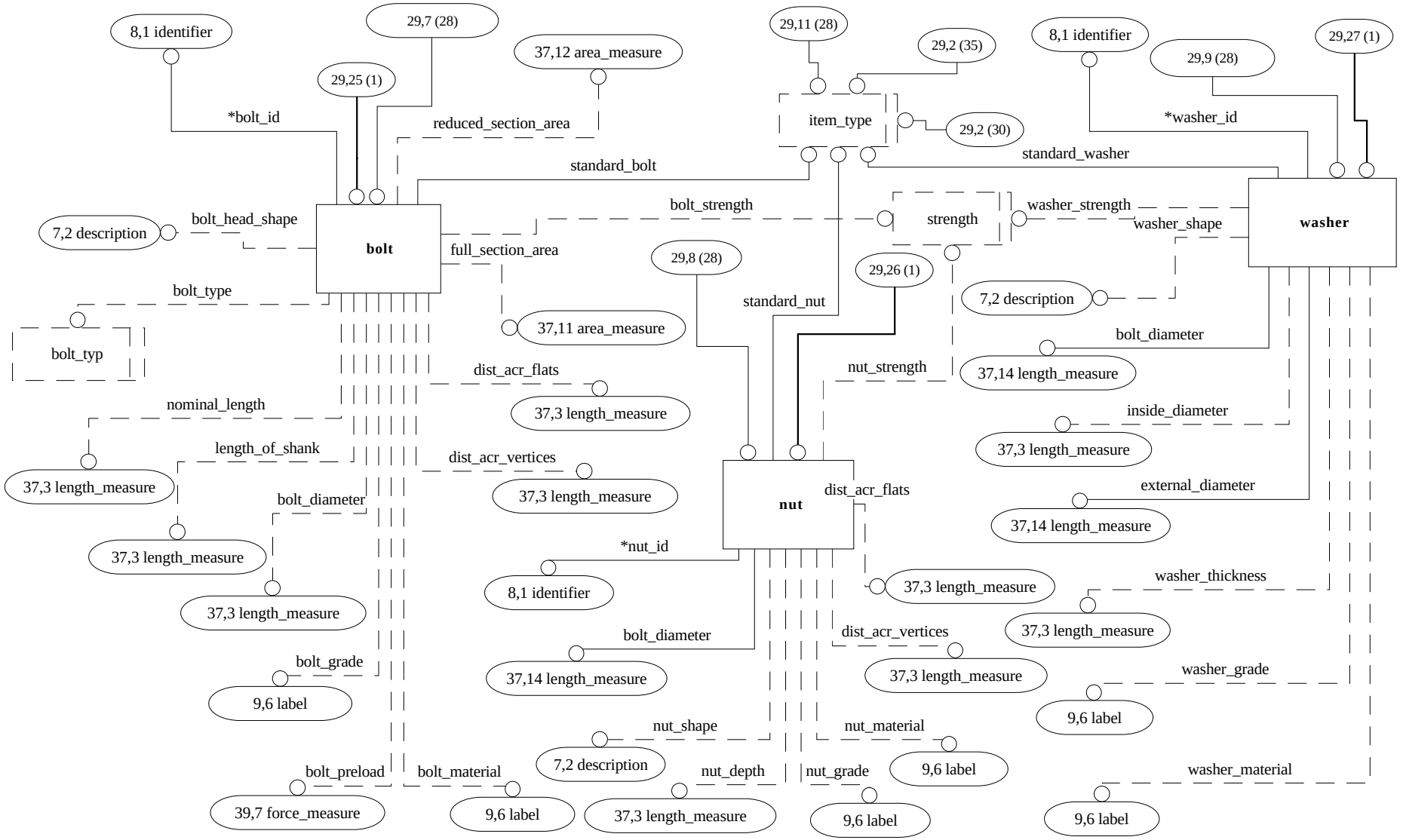

Figure G.29 - ARM diagram 29 of 40 in EXPRESS-G

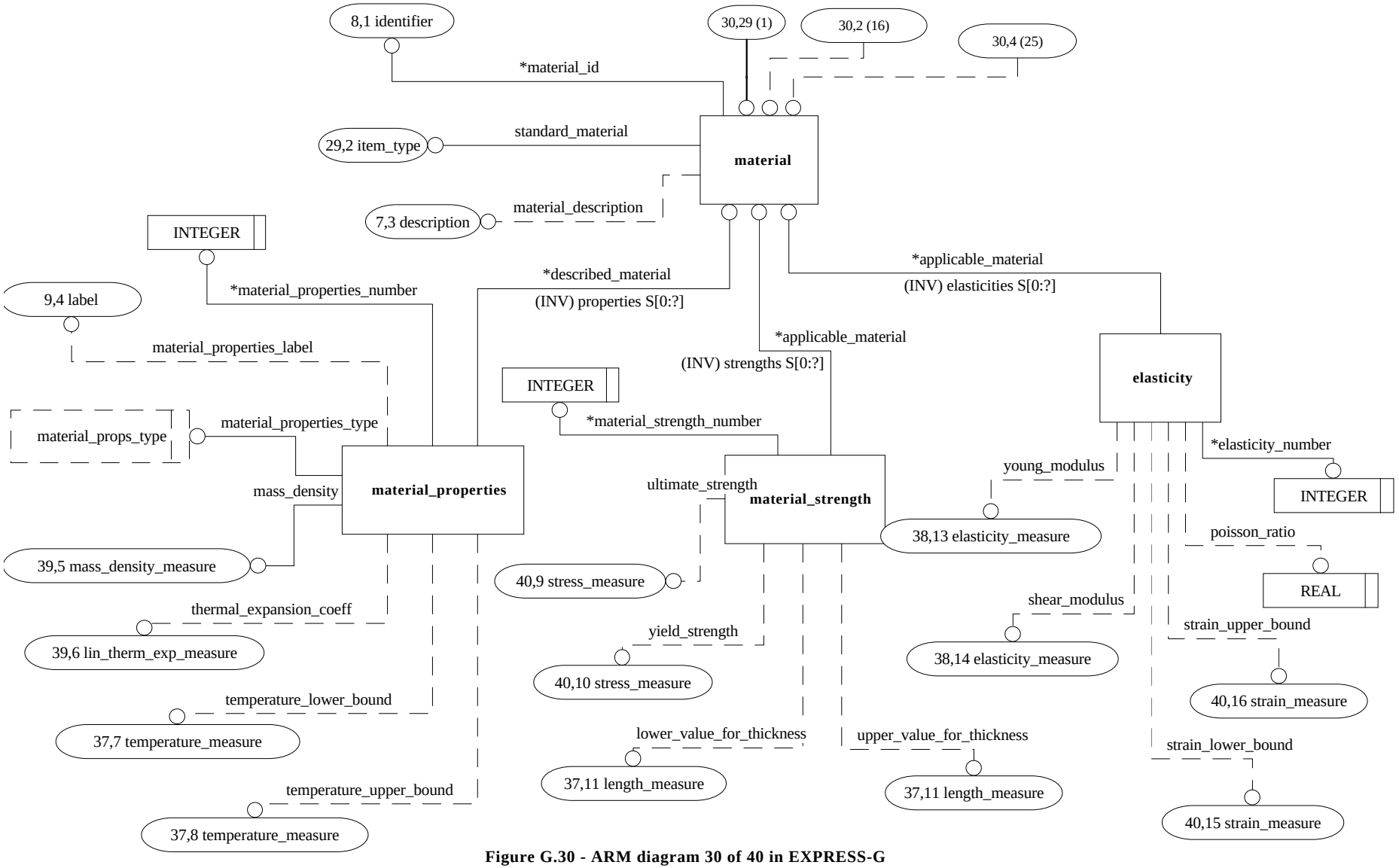

Figure G.30 - ARM diagram 30 of 40 in EXPRESS-G

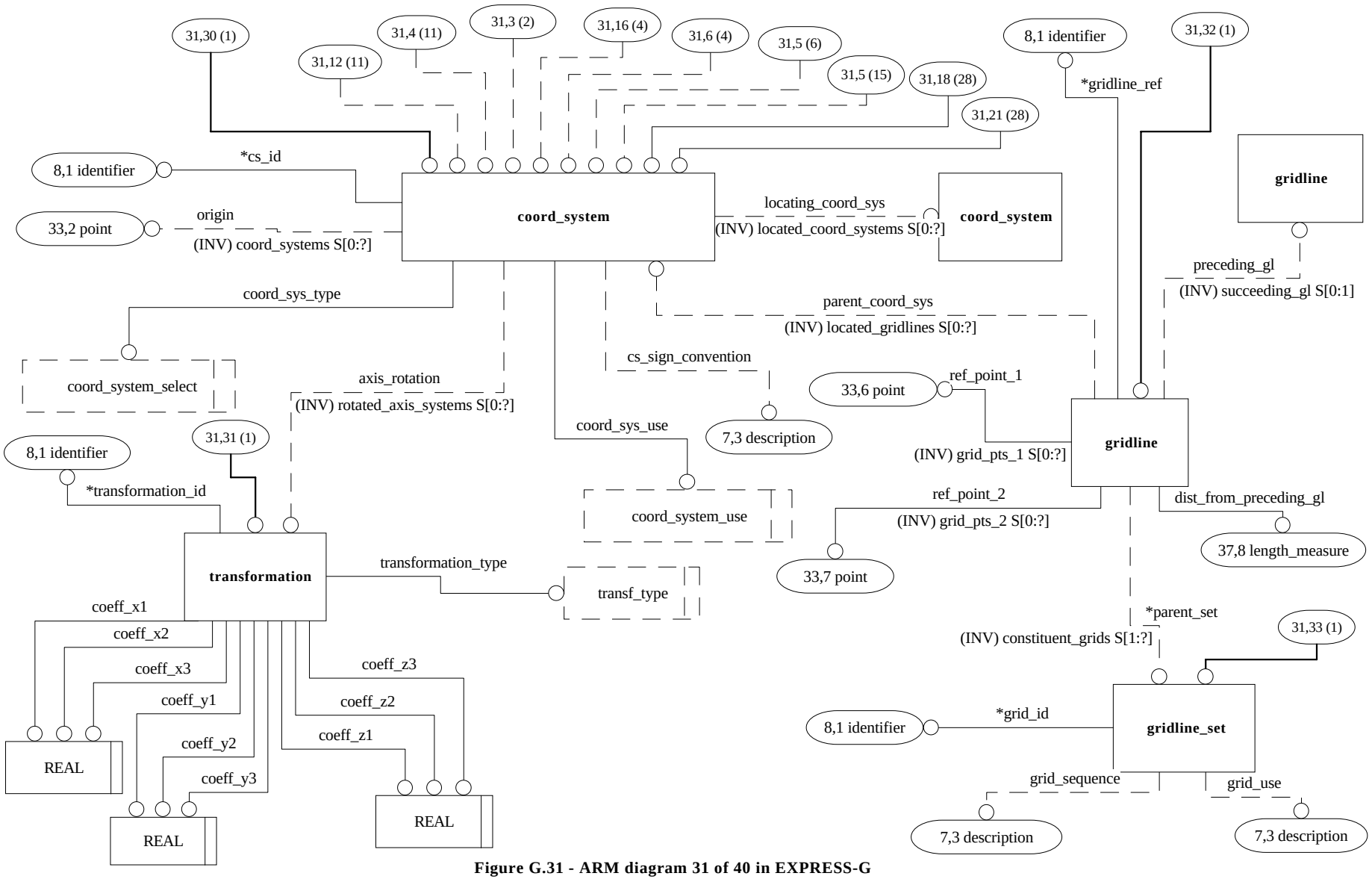

Figure G.31 - ARM diagram 31 of 40 in EXPRESS-G

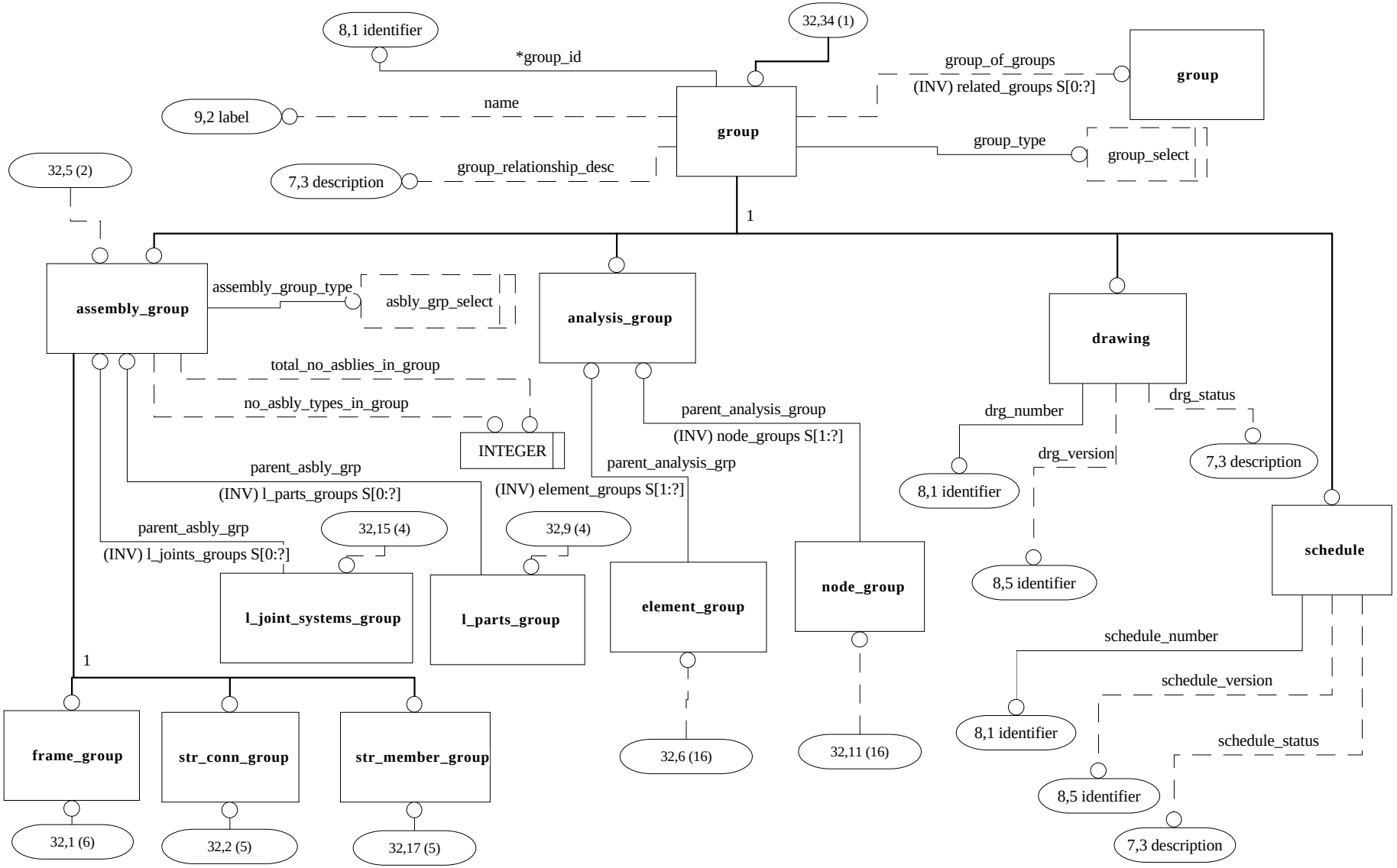

Figure G.32 - ARM diagram 32 of 40 in EXPRESS-G

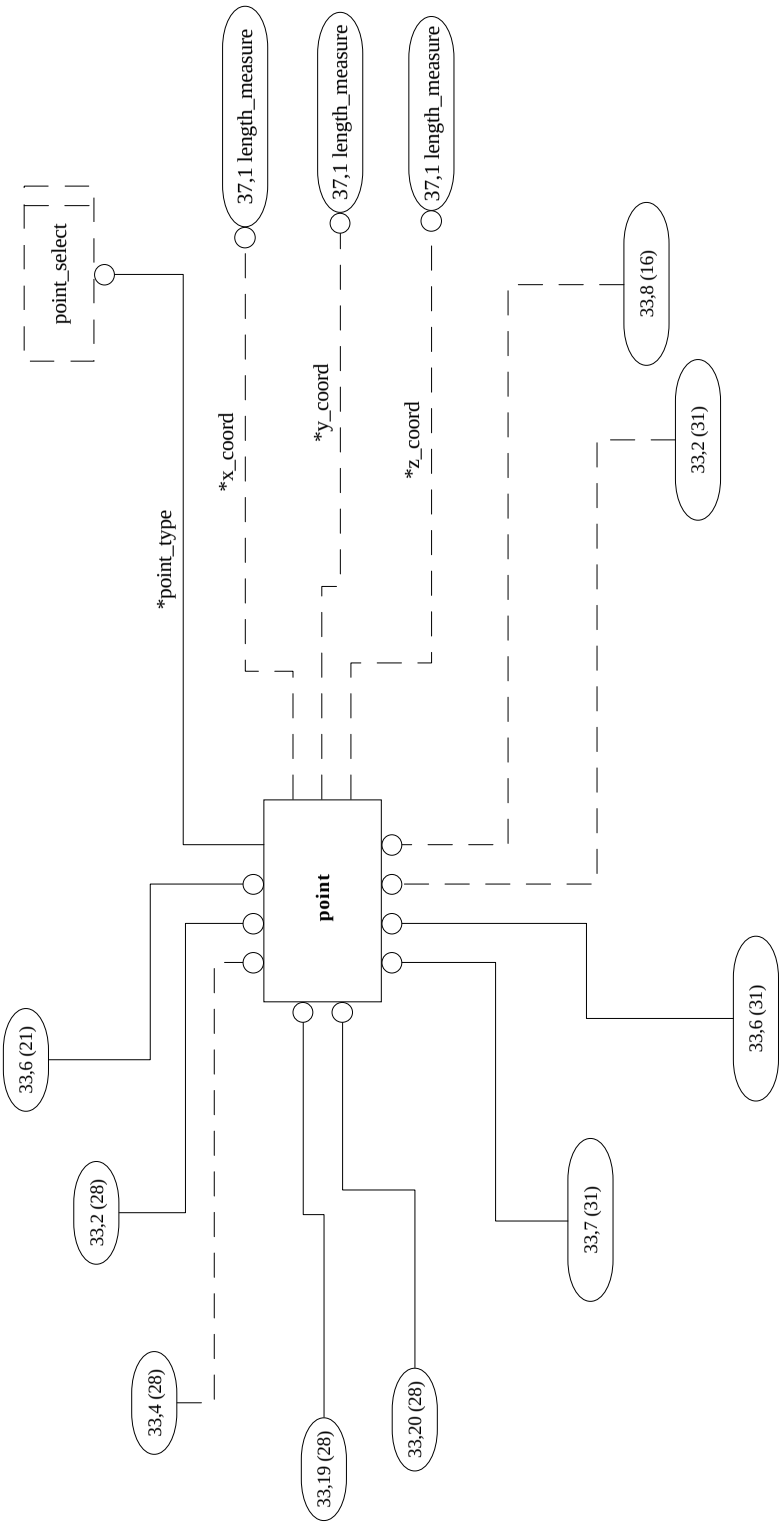

Figure G.33 - ARM diagram 33 of 40 in EXPRESS-G

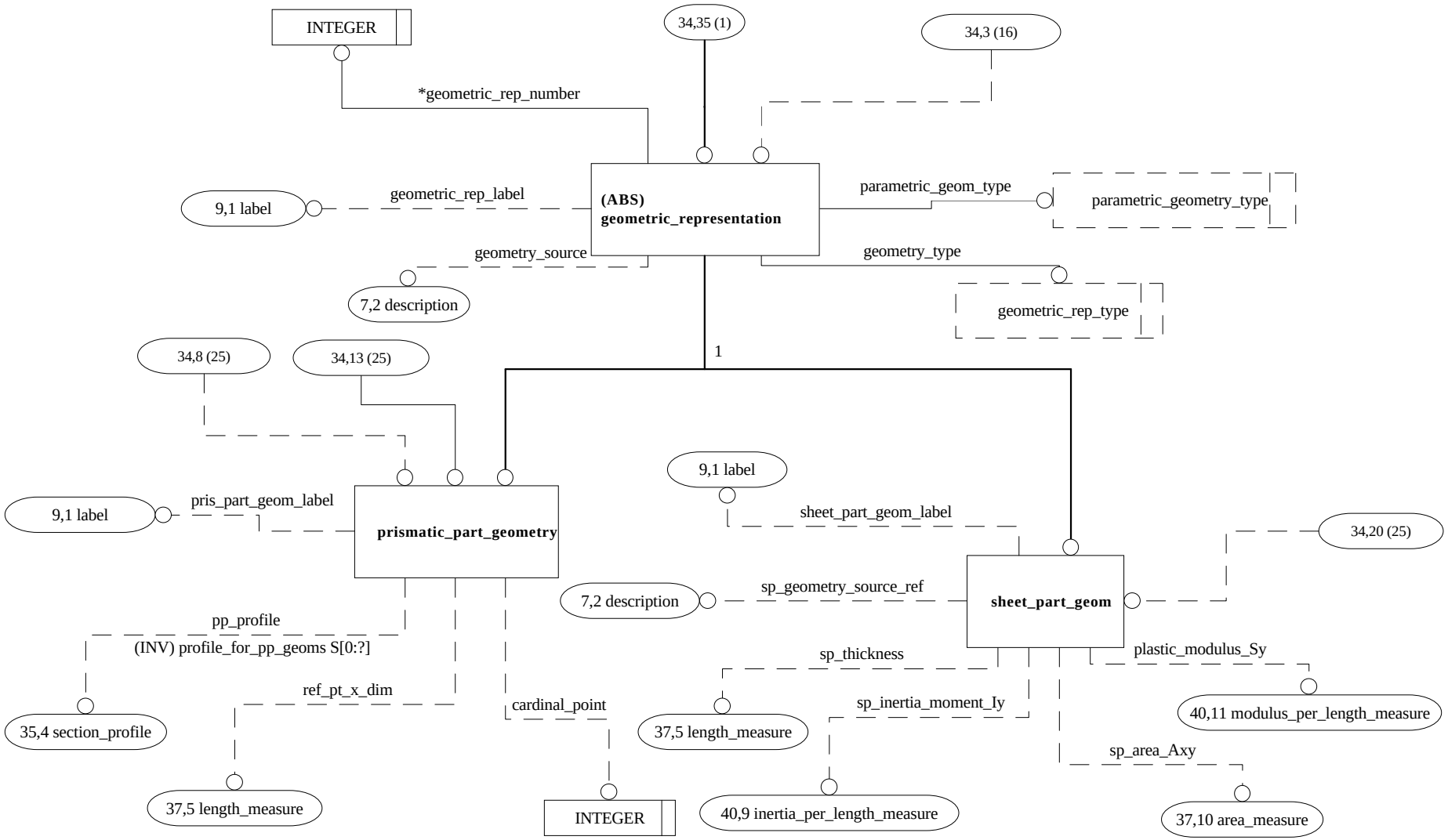

Figure G.34 - ARM diagram 34 of 40 in EXPRESS-G

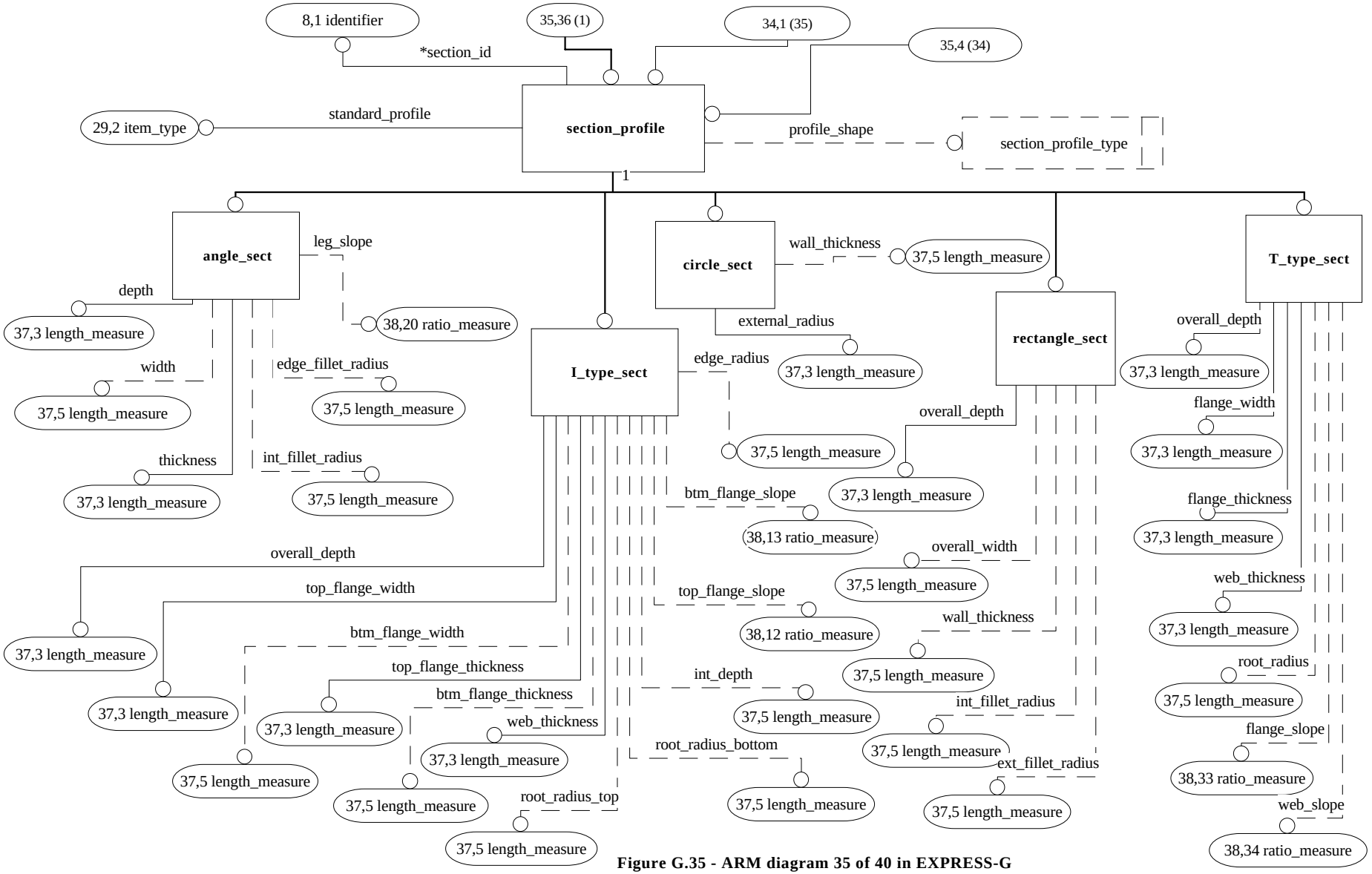

Figure G.35 - ARM diagram 35 of 40 in EXPRESS-G

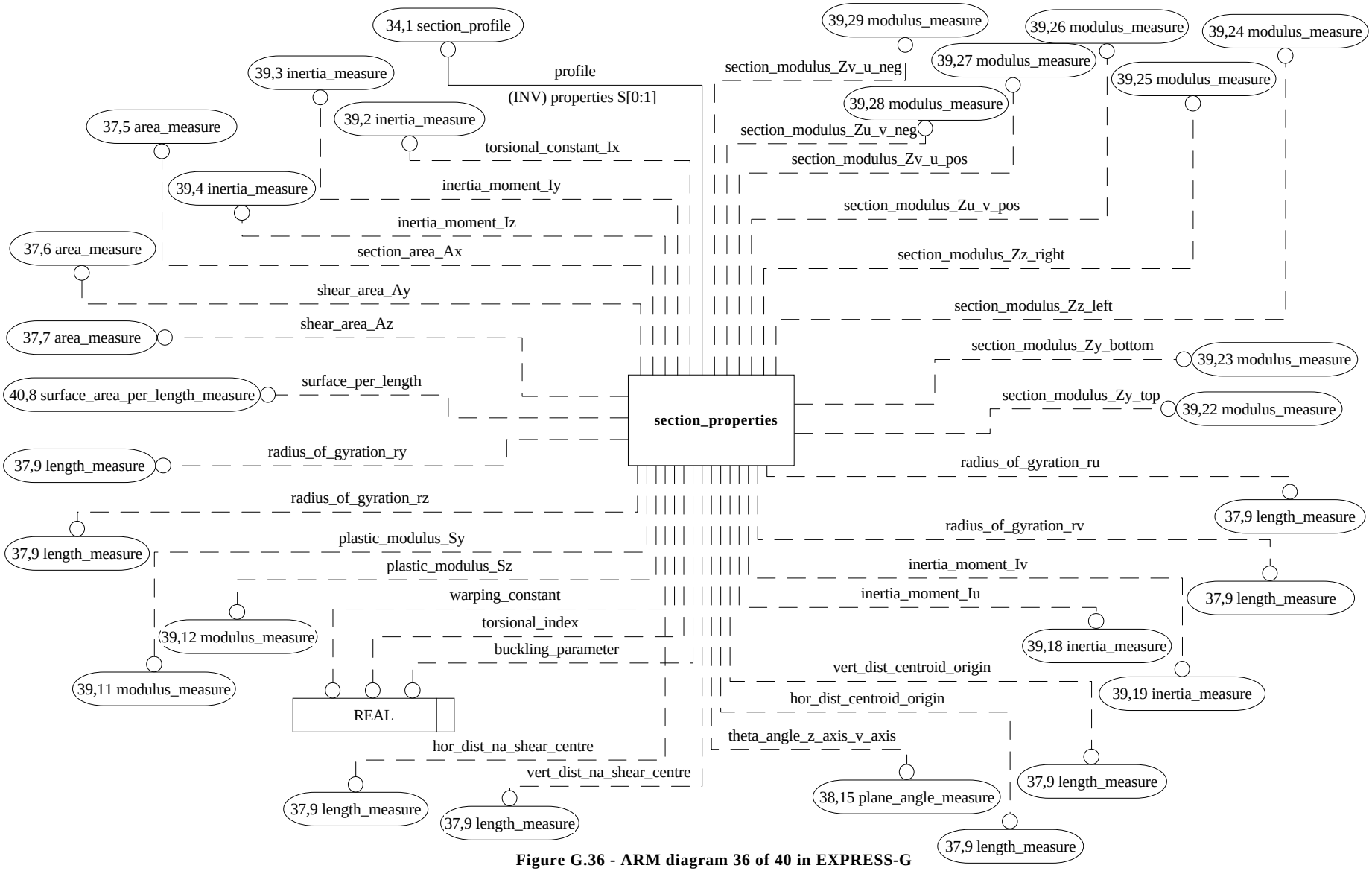

Figure G.36 - ARM diagram 36 of 40 in EXPRESS-G

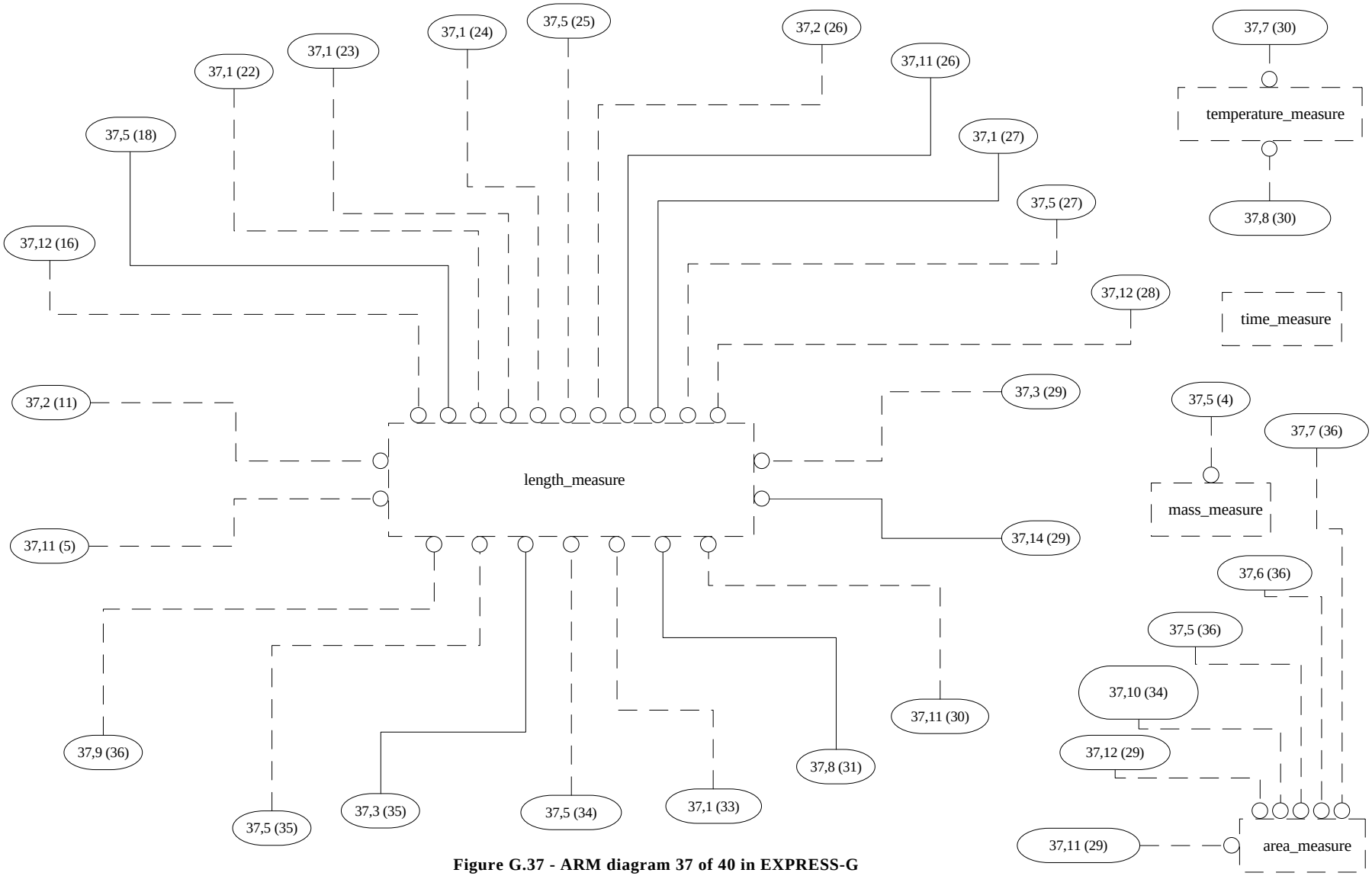

Figure G.37 - ARM diagram 37 of 40 in EXPRESS-G

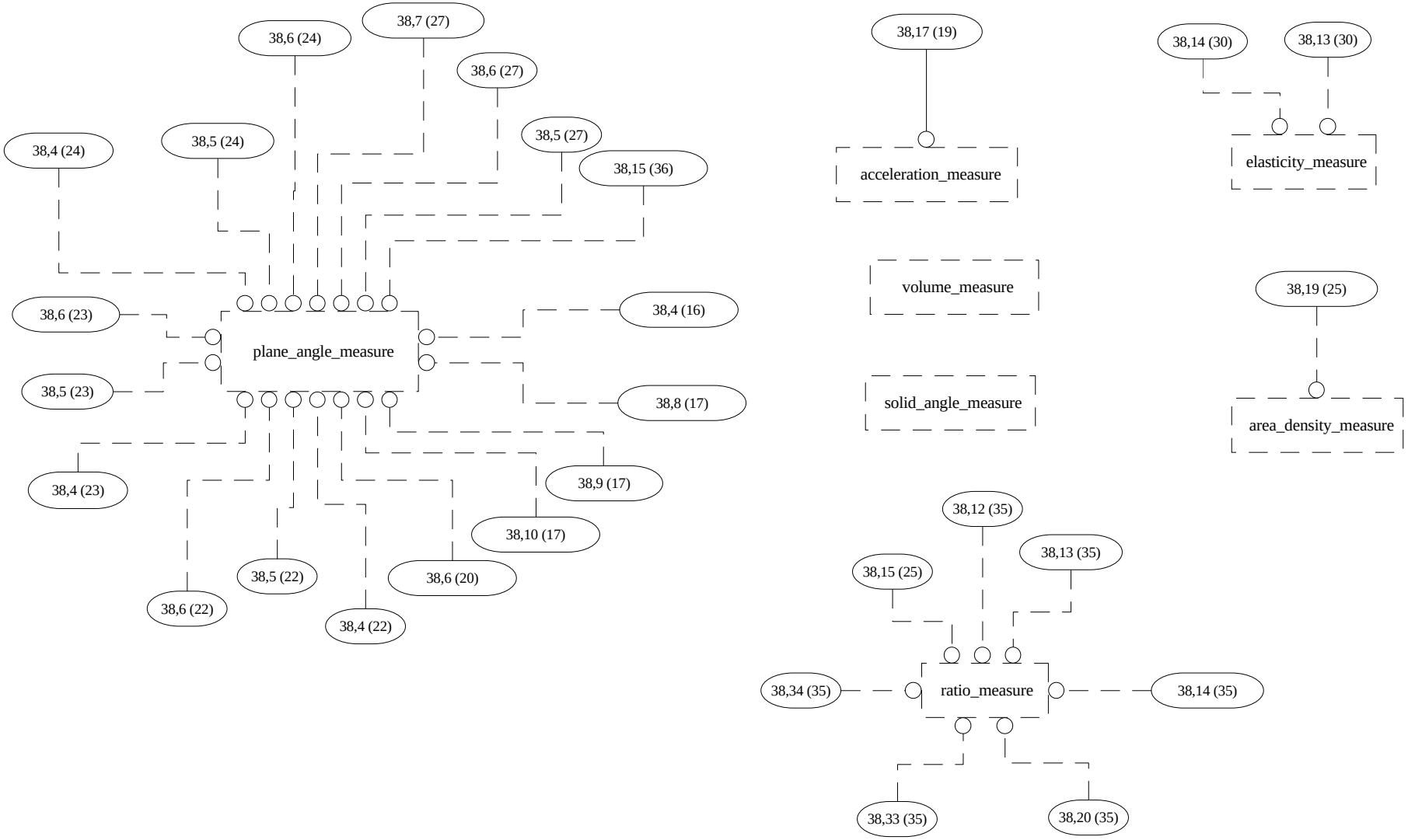

Figure G.38 - ARM diagram 38 of 40 in EXPRESS-G

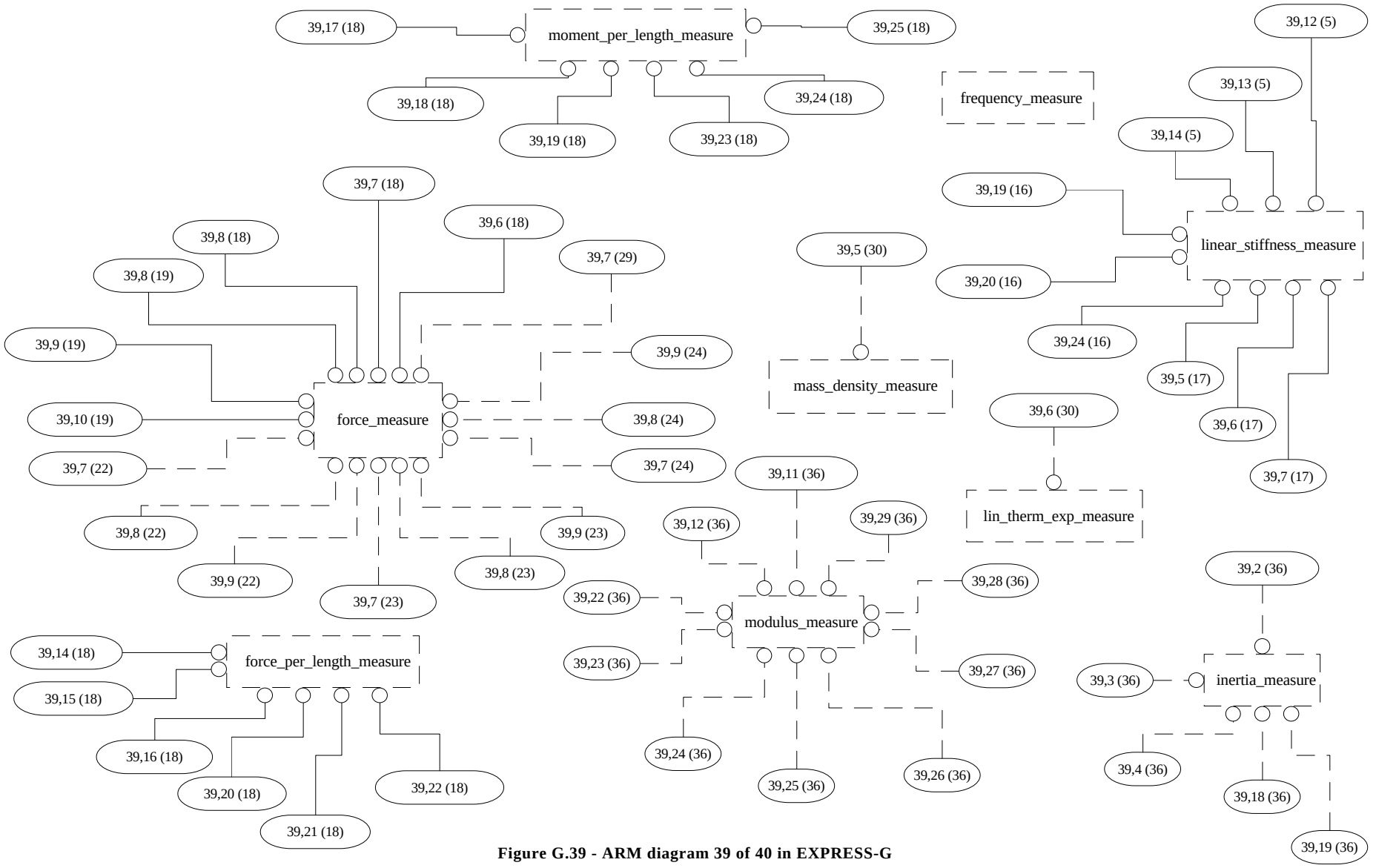

Figure G.39 - ARM diagram 39 of 40 in EXPRESS-G

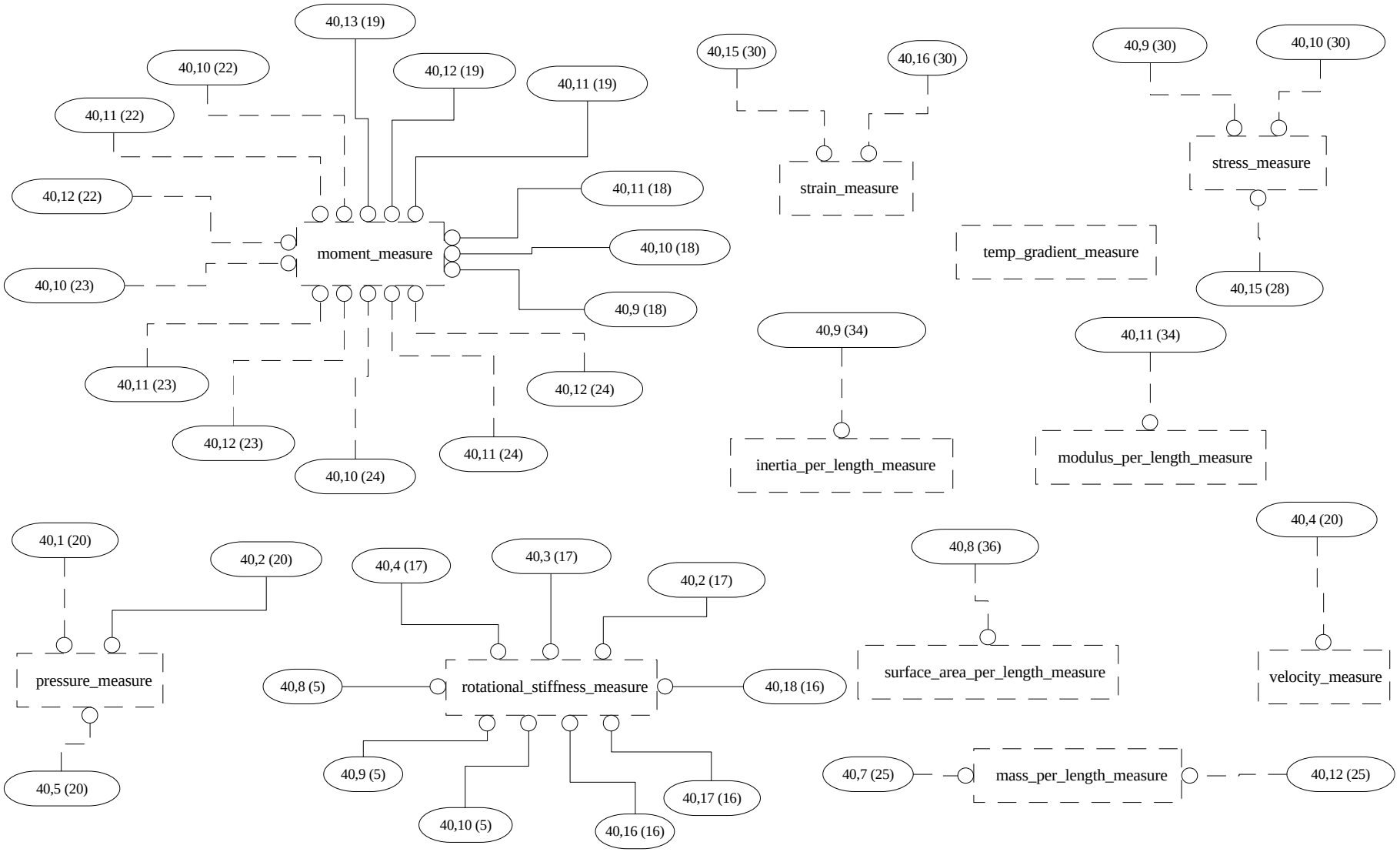

Figure G.40 - ARM diagram 40 of 40 in EXPRESS-G

Annex H
(normative)

AIM EXPRESS-G